CONTROL

SYSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

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JANUARY 1961 VOL. 4 No. 31

CONTROL

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Ploughing with controversy

OVER THE LAST FEW MONTHS there have been intimations in the daily press that the Government is to confer with industry on automation in this country. The Government's interest in this subject is of course known (or presumed) to exist because something about it appeared in the Conservative Party's manifesto before the last general election. This interest seemed to quicken soon after the Ifac Congress in Moscow last year,* for at least one of the newspaper statements about Lord Hailsham's plans was published in the wake of that important international gathering. A later announcement emerged in a report of an interview between Lord Hailsham and the scientific correspondent of the *Financial Times*. According to an article prominently featured on 4 November, 1960, the Minister for Science had agreed with the *Financial Times* correspondent that there might well be centralized Governmental study and help to industry in the field of automation. Lord Hailsham had added that the Government would get the Ministry of Education to organize an automatic control conference at Cranfield. The results of the meeting would guide the Government's subsequent moves.

All this seems to be fairly clear and very right, even if rather late. In fact, however, the situation is beclouded and bewildering. Naturally, much interest has been aroused among control engineers by the published statements; and, just as naturally, *Control* readers have been asking us for more information about the forthcoming conference. We have done our best to obtain it. We have approached the Minister for Science, the Ministry of Education, and the College of Aeronautics at Cranfield—and we have been mystified by the responses. While the timing of the press reports may have conveyed a sense of urgency in the Government's treatment of this matter, some of the principals in the affair seem to be thinking in terms of distant possibilities: and 'distant' in this context means something like five years away. Indeed, judging by the hesitancy of the replies that we have received to our enquiries, the possibility itself is in doubt, and we find it only too easy to infer that behind the scenes there is a battle being fought between people who are in favour of a conference and others who are against it. (Let us hope at least that the cause of the conflicting appearances is something as positive as this, rather than that it is merely the traditional muddle, or, still worse, an oblivious languor.) If there is anything like a hidden struggle really going on, those who must await the outcome are left to wonder whether the contenders seek mainly for narrow political ends or more for the technological health of British industry. It is impossible to expect completely disinterested judgement from any man, politician or other, but for the sake of the country we pray that on this issue the broader minds prevail. May action be determined soon through the logic of foresight rather than compelled late by the logic of events.

Would it be a good thing for the Government to intervene in an attempt to boost automatic control? This is a deep question, touching so many sensitive spots that one can scarcely express an opinion without betraying or arousing more or less passionate personal prejudices. Possibly a measure of Governmental participation is unavoidable, and the real question for many people may be only how much and in what manner the state should contribute. Thus there are control engineers who consider that a co-ordinating body on the professional level, independent of the Government, is all that is necessary, but state finance without strings would presumably not come amiss to them. Nevertheless, there are other men in the industry who are firmly and comprehensively 'agin the Government' in its every fresh manifestation, and they urge that the country must wring all it can out of existing organizations without upsetting manpower distribution and programs of work already in hand. Vigorously opposed to these advocates of *laissez-faire* are those who say that, since this is an age of large teams researching on large projects in large laboratories, and since automation is vital for the nation's economic well-being, there needs to be a Government research establishment devoted entirely to automatic control.

Clearly there is fertile ground here, ready for ploughing with controversy and planting with policy. A rich harvest would surely be the reward of good husbandry. Since controversy there is, let it be public and let the Government take a hand. A national conference (and why not at Cranfield?) would be an excellent thing now, but in five years' time it may be too late.

*Fully reviewed in our July, August and September issues

VIEWPOINT

John C. West, Professor of Electrical Engineering at Queen's University, Belfast, does not consider control as a separate subject, but as . . .

THE VERY ESSENCE OF ENGINEERING

The international conference on automatic control held in Moscow last summer emphasized that this field has developed into a vast science over the post-war years. It is not even one subject, and a specialist can only cope with one branch and its related and cognate topics. The Moscow conference was subdivided into twenty-one classifications, but even then some papers were misfits.

Automatic control is undoubtedly of considerable importance to industry. It is vitally necessary for the economic progress, or even survival, of a country such as ours. To a scientist the scope is wide enough to cover all shades of interest, starting from the intensely practical, with specific applications in many branches of engineering, and finishing on an exalted plane of mathematical generality and erudition. The educationalist, especially in the university, sees automatic control as a new and powerful discipline. It is fundamental, it is inescapable; but it is *not* one more new subject to be added to an already overcrowded syllabus. It is a new philosophy, a new approach to engineering outlook; it embraces both the old and the new engineering topics. Subjects classically separated many years ago, such as dynamics and applied mechanics, electrical rotating machines and electronics, must be integrated into systems which can only be taught and analysed as a whole.

The major topics in engineering undergraduate courses have been built up around devices. Mechanisms which differ fundamentally in their method of operation have been expanded in their technical context to become separate subjects for degree examination. However, no device operates on its own, except perhaps in the teaching laboratory. In real life it is affected by its environment and in turn reacts on this environment. A multiple sequence of cause and effect takes place, the full understanding of which cannot be achieved by isolated studies of the various devices. It is also unfortunate, to say the least, that the characteristics of the isolated devices taught and emphasized at the present time are not those required for the appreciation of their performance when they form individual parts of a complete sequence. 'Control' is the study of the performance of interlinked and related devices, whether designed as a completely automatic feedback system, or with the loop closed inherently by human action.

Efforts are being made in many quarters to establish degree courses in automatic control, the thesis being that this field is as important as the accepted schools of civil, mechanical, electrical and aeronautical engineering. I think that this is basically wrong: 'control' is the very essence of engineering and not some new subject. The fundamental principles are simple, and, to be understood, do not need a knowledge of branches of mathematics not already taught to engineering students. What is required is that every teacher in engineering be educated in the wider aspects of control theory, so that the basic courses already in existence may undergo an orientation of outlook and analysis towards the more fundamental 'control' point of view. The classical subjects would be enriched by this approach.

Certainly those who wish to become specialists in the control field must be catered for by specialist courses in the later part of their degree work, by postgraduate courses of teaching and research, and, if necessary, by specially created institutions. The specialist, however, cannot to any extent alter the outlook of the practising engineer who forms the mainstay of industry. Before the revolution in automation—prophesied fifteen years ago—can take place, a revolution in the training of the engineer must be accomplished.

John C West

LETTERS to the EDITOR

Significant figures

SIR: I read Mr Sutherby's article in your November issue with considerable interest, because this on-line-computer-control business seems to be the coming thing. "It is significant," writes Mr Sutherby, "that more than 38 computers have now been sold in the United States for on-line application, and a market of sixty has been predicted for this year." We ARE backward in this country, aren't we! But wait: a few pages away in that same issue of your excellent magazine I read Mr Medlock's entertaining report of the American I.S.A. exhibition. "It would appear," writes Mr Medlock, "that there are about six 'on-line' controlling computers claimed to be actually working in the U.S.A." $6 \div 38 \simeq 16\%$. Is this significant too?

Woking P. K. KILMUIR

● *Mr Medlock writes: 'Although Mr. Kilmuir's apposition of data from the two articles in the November issue of "Control" is commendable, I would not care to attach too much significance to it.*

'In the first place the cautious wording of my article should be noted: "It would appear that there are about six 'on-line' controlling computers claimed to be actually working in the U.S.A." The figure of six originated from my own judgment and seemed a fairly safe minimum figure, but it was less than that claimed by some people with whom I discussed this subject. In making claims, it is better to be guilty of conservatism than of exaggeration, and maybe I have done less than justice to our American friends.

'Secondly, one must not forget the time which elapses between (a) placing the order, (b) delivering the equipment, and (c) completing the commissioning. Unfortunately, an ambiguity exists in the phrase "have been sold". Strictly speaking, an article is only sold when it has been delivered and invoiced, but unfortunately there is the common usage of the phrase to mean that the article has been ordered. Perhaps Mr. Sutherby could clarify this point; it is important because a whole year could conceivably elapse between the ordering and the delivery, and perhaps another year or longer before the computer is finally programmed and entrusted with "on-line" computing. It has been stated[1] that some users delay the final step and use the computer for design studies, using it as a data logger.

'Thus the "on-line" computer in use today was probably ordered two, three or more years ago[2] when the order rate was very low. Bearing in mind that the development of "on-line" computers is only a few years old, I feel that it is not a fair criterion to relate the number of sets of equipment ordered this year with the number of working installations.'

[1] I.S.A. Preprint NY60-107, W. S. Aiken, "Start-up of Process Control Systems".
[2] H. R. Karp, "Control Engineering", 7 (4) April 1960, 20-22.

● *Mr Sutherby writes: 'Mr. Kilmuir is, I think, stretching words to try and prove a preconceived idea. I copied the word "sold" from my source of information (Control Engineering, November 1959) and I admit "ordered" might be a clearer term. On this basis Mr. Medlock's figures of 29 machines ordered from one manufacturer suggest an even larger market. However I did not claim that the 38 sold were controlling, only that they were sold for on line application—data logging, process analysis and control. Mr. Kilmuir will do much better to obtain reliable data by reading papers, such as that mentioned by Mr. Medlock on the commissioning of a computer control system, and also by studying the figures for some of the acceptance tests which have been passed by American installations, than try to draw deductions from the comparison of independent figures such as mine and Mr. Medlock's'.*—EDITOR

By numbers

SIR: In reply to S/Ldr. Flegg's letter in your November issue, we prefer to say, in any particular context, 'this is how we do it' rather than 'this is the absolutely unique and only way in which it can be done'.

Historically, Heaviside used 'operational calculus' (in which p was the operator d/dt) with consummate skill himself, but his methods were not clearly explained to the satisfaction of contemporary Cambridge mathematicians; van der Pol* therefore developed 'symbolic calculus' in which p was a number and a time function $h(t)$ and its 'image' or 'operational equivalent' $f(p)$ were regarded as in different 'worlds' and the fundamental relation between them was

$$f(p) = p\int_0^\infty e^{-pt}h(t)\,dt \qquad (1)$$

Later, Laplace-transform technique was developed, especially in France, and $F(s)$ was defined to be the 'transform' of $h(t)$ where s is also a number and

$$F(s) = \int_0^\infty e^{-st}h(t)\,dt \qquad (2)$$

so that

$$f(p) = [s\,F(s)]_{s=p} \qquad (3)$$

Later, van der Pol and Bremmer† developed 'general transform calculus' in which p was still a number but the lower limit of integration in Equ. (1) was replaced by $-\infty$, which here means merely a number sufficiently negative to lose no part of the integrand, so that making the lower limit still more negative makes no difference. (Only Riemann integration is involved since there is no point in

seeking the highest possible value for this lower limit.) Thus symbolic calculus is a special case of the abovementioned 'general transform calculus' and so is Laplace-transform technique, with the additional disadvantage, as pointed out by S/Ldr. Flegg, of the loss of the factor s as indicated in Equ. (3). This loss results from a decision of the Société française de électriciens which we regard as unfortunate.

We prefer to follow Heaviside in using an operational approach, because all mathematical tools made available by Laplace-transform technique are then still available to us, but the operational method also gives a direct and simple solution in many important cases (such as that of frequency modulation) where Laplace-transform or symbolic-calculus techniques fail. The operational approach leaves us free to postpone until the final stage a decision as to how best to reduce an operator (expressed in the most convenient available form, in partial fractions perhaps), operating upon a given operand, to an explicit expression, free from ambiguities, contradictions and inadequately specified terms.

We also contend that the presence of the lower limit 0 in Equs. (2) and (3) implies, but does not expressly state, that the integrand is not $h(t)$ but $h(t)H(t)$ where $H(t)$ is Heaviside's unit step, zero for negative t and unity for positive t, whereas when the lower limit is $-\infty$, as in 'general transform calculus', the integrand (or original time function) does not contain a step factor unless explicitly defined to do so. The fact that a finite lower limit conveys with difficulty and by implication what is explicit when the appropriate step-factor is introduced was pointed out by Heaviside.‡

In the operational approach, since $d^ri(t)/dt^r \equiv p^ri(t)$, the effect of the operator $Z(p)$ on $d^ri(t)/dt^r$ is exactly the same as the effect of $p^rZ(p)$ on $i(t)$. But the corresponding relation in Laplace-transform calculus, translated into operational language, is not between the operator which will produce $i(t)$ and that which will produce its r^{th} derivative, but that between the operators which will produce $h(t)H(t)$ and $\{d^rh(t)/dt^r\}H(t)$. This difficulty is thus also due to the lack of explicit statement of the presence of $H(t)$ when the lower limit zero is used in the definition integral of the transform.

The main difficulty about the operational approach is that it is unfamiliar, but once the fact of this unfamiliarity is faced, the operational approach is soon seen to be very powerful, especially in the all-important respect of bringing complete understanding and enlightenment to those who have the courage necessary for fundamental thinking. In the army, drill is done 'by numbers' on the assumption that the soldier is too stupid to understand the significance of what he is doing. This assumption is not justified in the case of soldiers, and still less in the case of students, for whom Laplace-transform technique tends to be reduced to a kind of drill unless the teacher is particularly careful to avoid this temptation.

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*Pol, B. van der: *Phil. Mag.*, 1929, *7*, p. 1153; *8*, p. 861

†Pol, B. van der, and Bremmer, H.: *Operational Calculus based on the Two-sided Laplace Integral* (Cambridge University Press, 1950, etc)

‡Heaviside, O.: *Electromagnetic Theory* (Ernest Benn Ltd, London, 1925), Vol. III, p. 236

Exception at Interkama

SIR: We were most perturbed to read on Page 85 in the November issue of 'Control' the observations made under the sub-heading 'Tragic British Shadow'.

At the Interkama Exhibition we shared stand space with the Laboratoire des Basses Pressions. The British equipment here was neither dull, cramped nor uninspired and add to this the fact that throughout the whole of the exhibition, two members of our staff were in attendance, one of whom speaks German, and the other having German, Italian, French and Russian.

Certainly in our own case we found that the multi-lingual capabilities were a great asset in handling the very many enquiries we received.

We feel that this is an instance where your editorial column might be used to point out that whatever the British contingent may have done, we certainly went out of our way to put ourselves at the disposal of all visitors.

Appleby & Ireland Ltd W. JENNINGS

● *Mr K. C. Garner, who contributed the article on Interkama, writes: 'My criticism of the British effort at Interkama was entirely directed at the British Stand, Nos. 2025–6 in the catalogue, which was undoubtedly cramped, containing no less than twenty-six firms' exhibits, in a space suitable for only half that number. While the individual products, exhibited on the stand by some of our most reputable companies, were excellent in themselves, they were not, in my opinion, presented with sufficient impact and effect in relation to the magnitude of the rest of the exhibition.*

'Mr. Jennings is, of course, quite justified in emphasizing his firm's excellent presentation, which he considers was a successful venture. This indeed endorses my views.

'Maybe the low export figures for the control industry, as quoted in the editorial of the Industry Guide and Digest, recently published by CONTROL, *are also a related phenomenon'.*—EDITOR.

For the record

SIR: In the survey of Miniature Recorders manufactured in U.K., published in the November issue of 'Control' it was inferred that our MINICAN Temperature Recorder (referred to as Minicam) is a panel mounted instrument.

We would like to clarify this for the benefit of readers, by stating that the instrument has been designed to be introduced as a whole into a process system.

The size of the thermometer bulb and recorder combined ($6\frac{1}{2}'' \times 2\frac{1}{4}''$) has been determined in relation to that of food cans and bottles. By sealing the bulb in the container the instrument will record the temperature of the contents while the assembly passes through an automatic sterilizer or cooler. In fact it can be used to get the inside temperature history of any sealed off or continuously moving enclosure.

Cambridge Instrument Co. Ltd T. W. BRANT

SIR: Our clients, Firth Cleveland Instruments Limited have asked us to bring to your attention a small error which appears on page 114 in the current issue of *Control*, in a table forming part of an article on control equipment by Mr. J. R. Spencer. In the table, the accuracy of the Firth Cleveland potentiometric recorder (Type MR 1035) is given as $\pm 0{\cdot}1\%$. We have been asked to make it clear that the true figure should be $\pm 0{\cdot}5\%$. We think the error may have arisen because the instrument has a sensitivity of 0·1%.

Dixon & Partners Ltd J. K. HILL

● *Mr J. R. Spencer writes: 'I regret that, possibly by including it in the survey table, the impression may have been given that the Minican is a panel mounted instrument. Apologies also to Firth Cleveland (and your readers) for the rather optimistic figures given for the accuracy of their Recorder.'*—EDITOR

Beginning a new decade

Control engineering in 1960

by **H. H. ROSENBROCK**
Constructors John Brown Ltd

THE OUTSTANDING EVENT in control in 1959 was without doubt the successful launching by the Russians of two lunar rockets. If one is to choose an outstanding event in 1960 there is again only one choice, and again it is associated with Russia—the Ifac Congress in June, held in Moscow.* Yet, if the rockets were a complete success, the Ifac Congress must be counted as a misfire for the Russians. Private comment in Moscow was largely unfavourable, and published accounts, especially in the U.S.A., have been very critical of what Russia had to show.

I have no wish to add to the great amount that has already been written on these lines. But I think we can now look back at the conference from a more general viewpoint and see how it has contributed to the development of control. There is no doubt that the conference did in fact mark a turning-point: a subject which can attract twelve-hundred delegates to hear nearly three-hundred papers amounting to about a million words is no longer in its infancy. The breadth and scope of the subject, after allowing for all that was repetitive and well-known, were no doubt surprising even to many who were already deeply immersed in it.

The conference was also important from another point of view. It was the first time that the Russian and the western work had been confronted on a large scale. On each side work had gone on independently and a divergence of outlook had arisen. In the west this divergence was largely due to ignorance or neglect of Russian work. On the Russian side, where knowledge of western publications is widespread, it seems to have arisen from an academic outlook which rejected the empirical and opportunist approach of the west. To us, the Russian work seems often to be pointless theorizing, which adds nothing to our practical ability to do a job. To them, our theoretical background must often seem insufficiently rigorous to support the load we place on it.

These differences are partly due to differences of temperament and partly to differences of technical conditions on the two sides. In Moscow the most obvious thing was that Russia had much to learn from us: that most of the practice and most of the applicable theory had come from the west. In retrospect, however, the Russian work becomes more significant. Besides the art of control, and the technical methods used in it (in which the west has excelled) there must also be an intellectual framework or discipline. It is this discipline which must be taught to students of control, and which must determine the course of theoretical research. In the long run, stagnation of the intellectual discipline will lead to stagnation of the art and technology, because the more able and ambitious students shun such a field.

Viewed in this way, some of the Russian theory gains in importance. The work on the 'principle of invariance', for example, has added little so far to the art, but it has brought into a coherent whole much that was formerly disconnected.* The work on variational principles by Pontryagin and others has served a similar purpose. It is in such a climate of research that we may expect the germinal ideas to flourish—the ideas which the technology must have if it is to progress. One of our objectives in the west must surely be to cultivate such a climate of vigorous theoretical research.

The corresponding lesson for Russia—that theory cannot long remain healthy without a basis of application—seems already to have been learnt. The Institute of Automation at Kiev was seen to be doing just the kind of practical development work that will be needed to transform their industry. This will be a long and difficult task, and no doubt in the course of it the theoretical work will be subjected to a type of criticism which it has not had to meet in the past. This interplay could have most interesting results.

Two active fields

Turning now to technical aspects, two fields have shown particular activity in the year. The first is optimal control, which can be understood in a number of senses. It may mean a type of control which seeks always for the best steady operating condition of the plant. Equip-

*Reported and reviewed in *Control*, July, August and September.—EDITOR.

*An introductory article appeared in *Control* last November.—EDITOR.

ment for this purpose was available some years ago in the U.S.A. (' Opcon '), but few applications have been reported. Similar but more ambitious equipment (due to Feld'baum) was shown in Moscow at the Ifac Congress. Other equipment on similar lines was made available in this country during 1960. Such equipment carries out automatically a hill-climbing process to seek the point of greatest efficiency—a procedure which has been done manually with success for many years on chemical plants. The scope for automatic equipment is limited on the one hand by the inherent slowness of the procedure: after each change it may be necessary to wait many hours in order to assess its effect. On the other hand, when the procedure is very slow, it can as well be carried out by hand. Between this Scylla and Charybdis, the width of the navigable channel has not yet been determined.

Other types of optimal control have been proposed when computers are used to control a process. These often rely on a mathematical model, held inside the computer, which simulates the behaviour of the process. The computer carries out its hill-climbing procedure on the model, thus circumventing the delays which would occur in experimenting on the plant itself. This approach obviously throws the difficulties on to an earlier stage, that of providing the mathematical model. It is understood that efforts to provide such models, involving a detailed and prolonged study of the plant, have often given an unexpectedly large improvement in efficiency through the increased understanding they have brought about, even without using the computer.

Something over twenty computers have now been, or are being, installed for on-line control of processes. It is believed that few of these applications use the advanced techniques of optimal control which have been put forward in the literature. Most carry out a program control (as in the starting-up of a power station) or are designed as simple replacements for the plant operator. No detailed analysis of operating experience with such an installation has yet appeared.

Another sense in which optimal control can be understood is as control which is made to depend on the response to the environment. A computer which updates its own model of a plant according to the measured behaviour of the plant is an example. So are many types of ' learning machine '. This last approach, stemming from a biological analogy, has provided much stimulating thought, but has not yet closed the gap between speculation and application.

Finally there is the type of optimal control which has been discussed by Pontryagin, which is an exercise in the calculus of variations. The whole path of a rocket, for example, is to be chosen so that it arrives in a chosen orbit with the least expenditure of fuel. Or the temperature profile along a chemical reactor is to be chosen so that the yield of desired product at the outlet is as large as possible. This is a very active field, both theoretically and in practice, and considerable gains can be obtained in the chemical example.

The second field in which workers have been particularly active in 1960 is that of discontinuous control. The control may be discontinuous in time, as in a sampling system. It may also be discontinuous in magnitude, being quantized to a certain restricted number of levels. On-off control is an example, and as the number of levels is increased the system becomes closer to a continuous system—indeed in a digital computer one often thinks of the variables as changing continuously. Both types of discontinuity may be present together, and theoretical work on the problems involved has been done, particularly in Russia. This work has obvious applications in the on-line use of digital computers.

Equipment

So far as equipment is concerned, apart from on-line computers, there is little that can be said of 1960 that was not true of 1959 or will not be true of 1961.

This relative stability of accepted practice was well-shown at the Interkama Exhibition,* held in Düsseldorf in October. Many electronic instruments were on show, and many manufacturers offered data-logging equipment, but no great emphasis was placed on these. More emphasis in fact was put by at least one German manufacturer on his recently-developed pneumatic instruments, supplementing his existing electronic range. Progress in Germany has been rapid, and a wide range of standard control instruments is now available there.

Another opportunity to study progress in Europe was provided by the seminar on ' analogue computation applied to the study of chemical processes ', which was organized by the Institut Belge de Régulation et d'Automatisme in Brussels.† This showed an increasing interest in the analysis of chemical processes, a good example being the study of the esterification of terephthalic acid which was reported by Rijnsdorp and others. There was also much interest in combined analogue and digital machines; perhaps a pointer to the future.

Steps in the right direction

At the beginning of last year, I suggested that one of the most important matters facing those of us who were concerned with control in this country was the training and status of control engineers.‡ Little progress was made with this problem in 1960, though many were working in various ways towards a solution. B.C.A.C. died during the year and rose again like the phoenix from its ashes.§ One wonders whether it is now a more purposeful bird, and hopes that it will prove so. It is known that the S.I.T. will in the very near future be announcing not only an educational program for post-H.N.C., but also plans for a change of name and structure. These are steps in the right direction, but there is still much to be done: in comparison with other countries it is doubtful if we are holding our own. To me this remains the chief problem for 1961.

**Control*, November 1960, p. 84.—EDITOR.
†*Control* (' News round-up '), December 1960.—EDITOR.
‡*Control*, January 1960, p. 72.—EDITOR.
§*Control* (' News round-up '), November 1960.—EDITOR.

The large number of production lines seems to justify further development of on-line control in conjunction with data logging

PART 2

Controlling the production of nylon yarn

by **R. N. ALDRICH-SMITH,** M.SC., F.INST.P., A.R.C.S., D.I.C.
British Nylon Spinners Ltd

The problems peculiar to manufacturing nylon yarn, the control of extrusion temperature, and denier control were discussed last month. This concluding instalment is concerned with moisture, humidity, temperature, and quality control

Moisture control

Immediately after extrusion, it is generally necessary to restore to the filaments at least part of the 4% moisture content necessary for equilibrium under normal ambient conditions. For this purpose, filaments are made to pass through a live steam zone before being wound up at the extrusion stage (Fig. 5). The filaments are wound on the take-up cylinder under controlled atmospheric conditions, so that final moisture equilibrium ('lagging') takes place fairly rapidly. Thereafter the cakes must be maintained in a controlled atmosphere before and during the drawing operation.

The control of atmospheric conditions under these circumstances consists of maintaining a uniform relative humidity, together with reasonable protection against wide or rapid changes in temperature. The actual value of r.h. is not critical between 55% and 85% and a compromise is therefore made between reasonably comfortable working conditions and the capital cost of air-conditioning.

Such plant consists of means for saturating at a suitable temperature the requisite flow of a variable mixture of fresh and recirculated air, together with the means for subsequent addition of heat in order to arrive at the correct r.h. The primary control loop comprises a saturation (dew-point) temperature detector, a controller and a set of fresh- and return-air louvres moving in opposition and operated from the same actuator. The saturating spray water is recirculated and, therefore, tends to take up a temperature corresponding to the wet-bulb temperature of the incoming air mixture. Since, for the required relative humidity, the dew-point temperature determines the final dry-bulb temperature (which need not be rigidly controlled), the dew-point controller is set for a fairly wide throttling range. This allows the dew point to be under control without supplementary heating or cooling for all except extreme external conditions. Under cold winter conditions, the louvres remain at their minimum fresh-air position and the dew-point drops to a value largely determined by the recirculated air wet-bulb temperature, which is maintained by virtue of the relatively high sensible heat load in the area. For areas where this heat load is insufficient, provision must be made for a separate control loop either to maintain the spray water temperature at the required minimum by live steam injection into the water sump, or to elevate the fresh-air intake temperature by a heater battery. In hot weather, the louvres remain at the 100% fresh air position, the dew-point rising in step with the outside wet-bulb temperature. As there is usually some evaporative cooling, the internal conditions remain reasonably comfortable with the dry-bulb temperature inside seldom exceeding that outside by more than a few degrees.

Humidity control is achieved by using a number of separate control loops—one for each of the distribution zones in the conditioned area. Each zone is supplied with the near-saturated air through a supply duct fitted with a battery heater controlled from a humidity transmitter. The latter is located where it receives a sample flow of conditioned air at a point as near as possible to the level and location of yarn processing. The air-flow and heater-battery capacity for a given zone is calculated on the estimated maximum and minimum net heat loads in the zone, leaving the battery-heater control valve to vary the temperature rise across the battery from a definite minimum of, say, 2 degF at 20% valve opening, to a maximum of about 8 degF at 80% valve opening.

An alternative method of humidity control depends on the psychometric fact that over a sufficiently wide dry-bulb temperature range, relative humidity is, for practical purposes, a function only of the temperature difference between dry bulb and dew point. To exploit this in practice, the dew-point temperature signal from the primary control loop is cascaded to the pneumatic set-point adjustment of the dry-bulb controllers at a 1: 1 ratio, thus preserving the economic dew-point variation. The dry-bulb controllers have both proportional and integral control actions in order to hold constant the temperature difference (and therefore the humidity) against changing area-heat loads. The well-known vagaries of wet-bulb systems and most humidity-sensing elements are thus avoided.

The uniformity of air conditions in the working space depends fundamentally on the distribution of the air (via ducts and diffusers) in relation to the sources of heat load in the area. The effect of good plant control can be wholly negatived by indifferent distribution. The initial adjustment of distribution is difficult, but the task is eased by plant control instrumentation which holds down plant variations while the necessary adjustments take place. The best method is to choose a period of steady dew-point and survey the working space with a radiation-shielded aspirated dry-bulb thermometer. Spots of persistent high and low temperature can be noted and the air distribution adjusted accordingly.

Such adjustments in distribution will ideally satisfy one particular pattern of heat load only, and if frequent changes are made in either the location or the energization of such heat loads, the corresponding changes in air distribution would be expensive to provide. In an area where many textile machines are installed, involuntary maintenance together with changes in machine utilization cause unpredictable changes in the pattern of heat load distribution, and therefore air distribution is in general far short of the ideal. In order to accommodate such changes, the tendency has been to increase the number of separately controlled zones in a given area, each zone supplying a smaller number of machines. This has also made easier the choice of location for the zone humidity or temperature transmitter.

Routine area checks on humidity and temperature are carried out either by a trolley-mounted Assman hygrometer with a battery-driven fan motor, or by trolley-mounted self-balancing bridge recorders having a gold-plated grid electrode in conjunction with a hydrophyllic solution, such as lithium chloride, as a humidity sensing element.

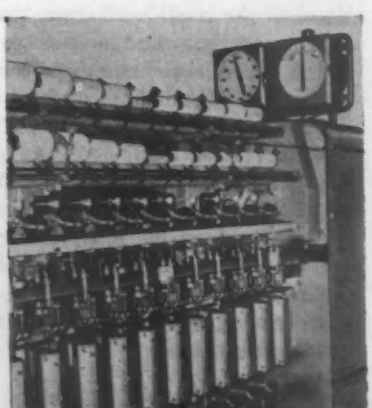

Fig. 8 Yarn bulking machine fitted with threadline scanning switch for monitoring all the heaters against local failure

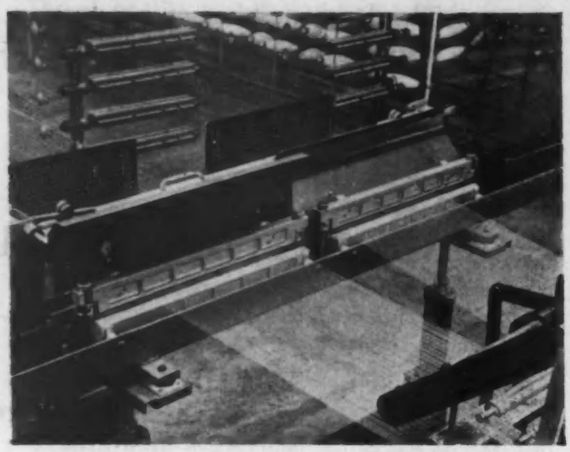

Fig. 9 Photo-electric warp inspector installed on a 21-in warping machine

Control of hot-drawing temperature

In drawing the heavier yarns to their final denier, the drawing tension can be considerably reduced by heating the filaments as they pass through the drawing zone. For this purpose, the filaments are made to pass over a heated platen long enough for the yarn to attain the platen temperature. Each threadline thus has its own heater, and the temperature variation with time, and that between heaters, will determine the uniformity of the resulting batch of yarn to a large extent. The problem is to maintain all heaters producing yarn to a given specification at a surface temperature within the required tolerances, and also to identify immediately any heater with off-standard temperature.

Each heater is fitted with a cartridge-type bimetal thermostat which is a close fit in a hole located near the heater surface. The contacts of the thermostat switch the heater elements to either the whole or approximately half the total wattage, giving two-step control action. A thermocouple of 30 s.w.g., iron-constantan wire is crimped inside a short length of copper tubing, the whole being a push fit into a $\frac{1}{8}$ in diameter hole just behind the heater surface. For ease of maintenance, the heaters are mounted on four-unit panels and wired by plug and socket connexions to the panel. The eight-core heater and thermocouple compensating cables from each panel are solder-jointed to the main cables leading back to a control cubicle at the end of the machine. The cubicle contains heater transformers and switch gear, whilst the control instruments are fitted to its end panel. One of these instruments is a multi-point scanning switch which selects each thermocouple in turn over a five-minute cycle, and indicates the identity of the corresponding heater. Each thermocouple in turn is thereby

coupled back-to-back with a reference thermocouple maintained at the desired heater temperature by a heater and precision thermostat. The temperature of the reference junction is indicated on a mercury-in-glass thermometer. The differential signal from the back-to-back thermocouples is chopped and amplified to drive a servo-operated pointer, with positional feedback, in another instrument which thus indicates the heater temperature deviation from the reference temperature. Limit switches on this latter instrument are arranged so that when the temperature deviation exceeds the preset limits, a prominently displayed lamp lights and the scanning cycle is interrupted until the operator presses a reset push-button. The indentity of the defective heater is noted for maintenance purposes.

The use of thermocouples in this way gives greater accuracy than if they were used in the conventional way, i.e. with cold-junction compensation and standardization of a potentiometer circuit. The expense of these latter items, with their contributions to error, is obviated and, moreover, the thermally-symmetrical thermocouple arrangement tends to cancel compensating cable errors, and only those errors sometimes attributed to localized metallurgical defects in the wire will be apparent. For the high-quality vacuum-melted iron-constantan thermocouple wire used, uniformity of thermo-electric characteristics is claimed to within $\pm$ 0·25% and we may thus expect the accuracy of temperature differential indication under these industrial conditions to be within $\pm$ 0·5%. This is rarely obtainable for conventionally applied thermocouples at the temperature level used.

Temperature control in yarn bulking

For many yarn end-uses the texture can be improved by disorganizing the regular array of filaments in the cross-section of continuous filament yarn. This may be done in several ways, such as forming filament loops or permanently distorting the filaments by combinations of heat, tension and twist. Since many of these bulking processes involve threadline heaters, temperature control is essential.

The control and monitoring system in some instances follows the same general lines as that for controlling hot drawing temperature, except that individual thermostats are not included, the heaters in general being of much lighter construction. The heaters are supplied from busbars at one of two voltages, this being dictated by the thermostat controlling a reference heater. A scanning switch monitors all heaters against local failure as before. Part of a typical bulking machine incorporating such instrumentation is shown in Fig. 8.

In another typical bulking process, the instrumentation is simplified by the fact that one heater strip along each side of the machine is shared by all threadlines, the current through the strip being adjusted at one of two levels by a simple thermocouple-operated, two-step temperature controller. Usually this system is supple-

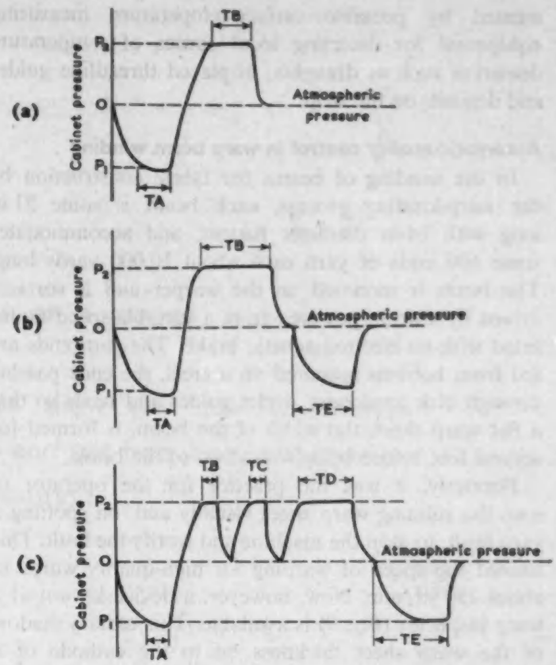

Fig. 10 Vacuum and pressure steaming cycles used in the crimp setting of nylon tow for staple: (a) steam cycle only; (b) steam cycle and timed re-evacuation; (c) repeated steam cycle and timed final evacuation. Code: P_1, initial vacuum setting; P_2, steam pressure setting; TA, time controlled by process timer—initial vacuum period; TB, TC, TD, times controlled by timers 2, 3 and 4, respectively—pressure periods; TE, time controlled by timer 5—re-evacuation

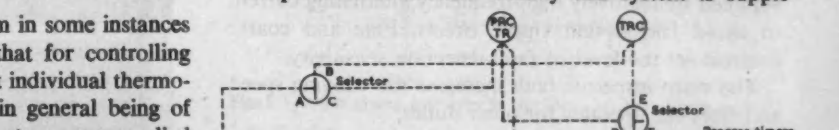

Fig. 11 Control diagram for crimp setting cabinet. Code: PRC, TR, pressure/vacuum recorder-controller, temperature recorder; TRC, program temperature recorder-controller. TT, temperature transmitter; ASV, solenoid-operated air valve; PI, pressure indicator; PSI, pressure switch with 29 inHg and 25 lbf/in² contacts; PS2 pressure switch to operate at 24 lbf/in²; PS3, pressure switch operating lights; TI, temperature indicator; TIC, temperature indicator-controller

mented by portable surface-temperature measuring equipment for detecting local causes of temperature deviation such as draughts, displaced threadline guides and deposits on the strip.

Automatic quality control in warp beam winding

In the winding of beams for fabric construction by the warp-knitting process, each beam is some 21 in long with 14-in diameter flanges, and accommodates some 600 ends of yarn each about 10,000 yards long. The beam is mounted on the warper and is surface-driven by a drum powered from a variable-speed motor fitted with an electromagnetic brake. The yarn ends are fed from bobbins mounted on a creel, the ends passing through disk tensioners, eyelet guides and reeds so that a flat warp sheet, the width of the beam, is formed for several feet before being wound on to the beam.

Formerly, it was the practice for the operator to scan the running warp sheet visually and, on spotting a yarn fault, to stop the machine and rectify the fault. This limited the speed of warping for high-quality warps to about 150 yd/min. Now, however, a device known as a warp inspector (Fig. 9) is available. This casts a shadow of the warp sheet thickness on to the cathode of a photomultiplier tube. The running sheet is guided by precisely machined and aligned guides both before and after it enters an accurately collimated light beam, so that the thickness of the shadow should normally correspond to the yarn diameter. A broken filament projecting laterally from any one end in the sheet will, as it passes through the light beam, cause a momentary decrease in the light reaching the cathode. The resulting anode-current change is amplified and caused to operate a relay and counter so that not only may the warper be stopped automatically before the fault reaches the beam, but the faults are also totalled. It is also possible for all detectable faults to be counted, whilst only those above a preset magnitude stop the machine.

Automatic compensation is provided for long- and short-term variations in lamp output, the lamp being supplied by relatively high-frequency alternating current to avoid background ripple effects. Fine and coarse controls set the level of fault-detection sensitivity.

The warp inspector both increases the winding speed and frees the operator for other duties.

Heat setting of crimped tow

In the production of nylon staple fibre, used largely for hand knitting yarns and woven pile fabrics, the continuously extruded intermediate is cold-drawn in the form of a tow of, say, 18,000 ends from 360,000 total denier down to 100,000 denier. This drawn tow passes directly to a crimping head where some twelve crimps per inch are impressed into the tow. Before the tow (in 50-lb bags) can be cut to staple, the crimp must be heat-set into the yarn and this is done by subjecting the bags to a combination of vacuum and pressure-steaming conditions in a jacketed cabinet.

The cycle combinations required for the various processes are shown diagramatically in Fig. 10 and the instrumentation is arranged so that by a single cycle-selector switch, any one of these can be brought into action, the cycle being carried out automatically with full safety interlocks operative. The basic control line diagram is given in Fig. 11, whilst Fig. 12 is a photograph of the actual installation.

Future prospects

The scope for further integrated instrumentation in synthetic yarn production depends to some extent on the development of extrusion and drawing processes. If the present general pattern of these processes is likely to persist, concentration on mechanizing manual operations would be worth while from the quality and productivity angles, if the remaining batch-processing characteristics could be minimized. This in turn depends on certain fundamental discontinuities, which await invention and re-thinking of the process for their elimination.

The large number of production lines appears to justify the further development of in-line process and quality control devices in conjunction with scanning and data-logging techniques. The emphasis here is on the development of simple and cheap transducers that could be fitted to each spindle for the continuous monitoring of such occurrences as yarn breaks and faults, or insidiously developing machine defects.

The employment of photo-electric devices and optical methods is likely to increase in view of the delicate nature of the threadlines in many processes. Also, since many stages of inspection are involved, the increasing use of such devices is likely to be favoured in order to

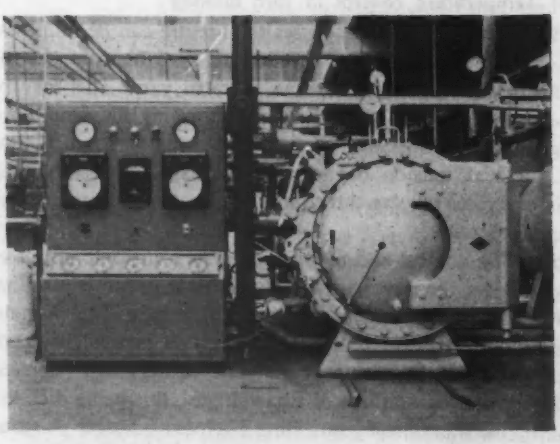

Fig. 12 Crimp setting cabinet with control panel

minimize tedious or mentally-fatiguing visual work, as well as to allow the stringent inspection standards to be met in a less subjective manner.

Acknowledgement

The author wishes to thank British Nylon Spinners Ltd for permission to publish this review.

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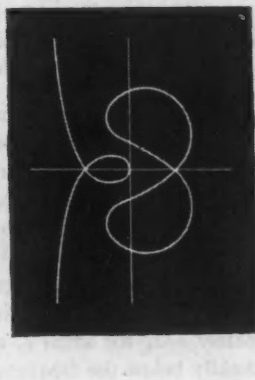

NUMBER THREE OF A SERIES

These examples show you how to analyse various systems and get frequency response by graphical examination

Pole-zero approach to system analysis

by **P. F. BLACKMAN**

Imperial College of Science and Technology

In last month's article the representation of complex frequency functions as pole-zero patterns was developed and some general properties of these patterns obtained. A particularly useful property is that general features of frequency response characteristics can be obtained easily from inspection of the pole-zero pattern, and the effect of parameter variations can be foreseen. The following article illustrates examples of patterns and some further properties.*

* Many examples of complex frequency transfer functions are given in (*1*).

EXAMPLES OF POLE-ZERO PATTERNS

(a) Pole and zero

If the *CR* circuit or spring-dashpot system considered in last month's article is reversed, as in Fig. 1, the general transfer has the form

$$T(p) = p\tau/(1+p\tau) = p/(p+1/\tau)$$

giving the same pole at $p = -1/\tau$, but in addition a zero at the origin, and the salient features of the frequency response can be obtained by direct inspection of the pattern as shown in Fig. 2. The zero at the origin

Fig. 1 Systems giving transfers of the form $T(p)=p\tau/(1+p\tau)$

indicates that there is no transmission of a constant voltage or displacement. For low frequencies there is a small transmission with phase lead $\pi/2$, while for high frequencies the two vectors acquire the same length and

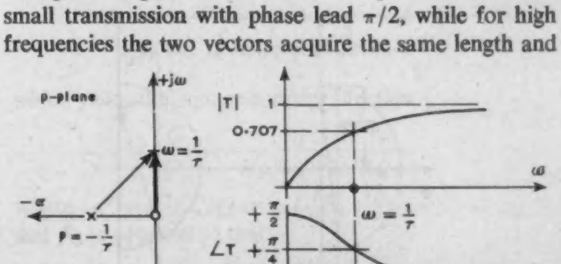

Fig. 2 Frequency response characteristics of the transfer $T(p) = p\tau/(1+p\tau)$

Corrections to last month's article in this series: 1 In the expression for Y/F(p) associated with Fig. 2, and for the mechanical time constant associated with Fig. 10, D should read C. 2 In Fig. 7 the point + 1 should be a zero, and the point + 1 + j1 a general point (indicated by a solid circle). In Fig. 13 the zero sign should be a general value.

become parallel, giving unity transmission with no phase shift. The elements of the constant-phase-and-magnitude network are shown in Fig. 3a, in which all lines are circular, there being a unit-magnitude line parallel to the imaginary axis. The form of the three-dimensional magnitude figure is also shown in Fig. 3b.

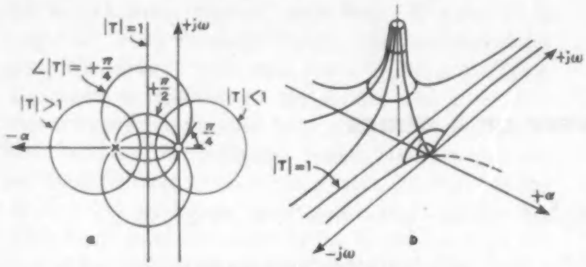

Fig. 3 a Elements of constant-phase-and-magnitude pattern
b Three-dimensional representation for
$T(p) = p\tau/(1 + p\tau)$

(b) Second-order system

For the spring-mass-dashpot system shown in Fig. 4, the steady-state input-response relation is governed by the equation

$$\frac{M}{K}\frac{d^2x_o}{dt^2}+\frac{C}{K}\frac{dx_o}{dt}+x_o = x_i$$

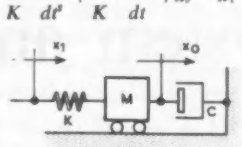

Fig. 4 Spring-mass-dashpot system

which yields the transfer

$$T(p) = \frac{X_o}{X_i}(p) = \frac{1}{(p/\omega_n)^2+2\zeta p/\omega_n+1}$$

where $\omega_n = \sqrt{(K/M)}$ and $\zeta = C/2\sqrt{(KM)}$.
The transfer gives two poles at

$$p/\omega_n = -\zeta \pm \sqrt{(\zeta^2 - 1)}$$

The motion of these poles in the (p/ω_n) plane has already been investigated in the first article of this series (Nov. 1960). If the damping is small, say ζ_1, the poles are complex conjugate, lying close to the imaginary axis in the plane on a unit-radius circle. As the damping is increased, say to ζ_2, the poles move back round the circle as in Fig. 5a.

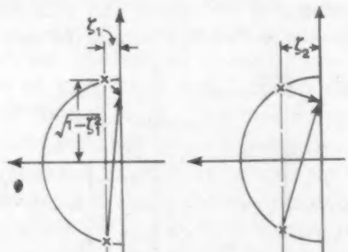

Fig. 5a Pole motion for second-order system with varying damping

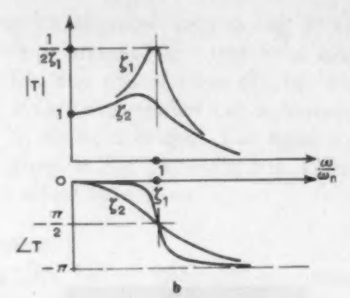

Fig. 5b General form of corresponding frequency characteristics

As the imaginary axis is traversed the variation of the two vectors gives the frequency response of Fig. 5b. If ζ is small, one vector passes through a minimum for a small change in frequency, giving a sharp maximum in the response. The phase angle will also swing rapidly through nearly 180° in the immediate vicinity of the natural frequency. By considering the length variation of the vectors it can be seen that the maximum response will be approximately $1/2\zeta$ for small ζ, and will occur at a frequency slightly below the frequency co-ordinate corresponding to the pole.*

The general form of the constant-phase-and-magnitude lines and the three-dimensional magnitude plot are shown in Figs. 6a, b. The two 0° lines from the poles

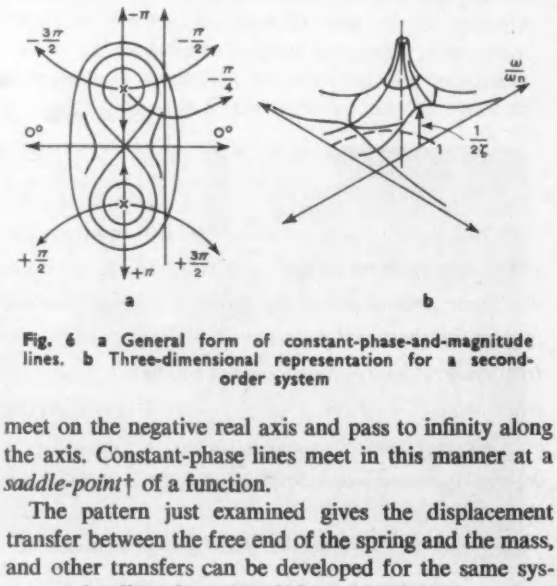

Fig. 6 a General form of constant-phase-and-magnitude lines. b Three-dimensional representation for a second-order system

meet on the negative real axis and pass to infinity along the axis. Constant-phase lines meet in this manner at a *saddle-point*† of a function.

The pattern just examined gives the displacement transfer between the free end of the spring and the mass, and other transfers can be developed for the same system and salient features of these transfers determined from examination of the patterns as in the following examples.

The transfer between a force applied at the free end of the spring and the mass displacement x_o, as in Fig. 7, can be obtained from the equation

$$M\frac{d^2x_o}{dt^2}+C\frac{dx_o}{dt} = f_i$$

*Additional information can be obtained directly from the pattern (2).
†That is, a point where $dT(p)/dp = 0$.

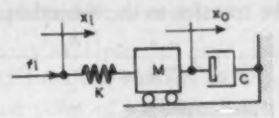

Fig. 7 Second-order system with force on free end of spring

and complex frequency substitution leads to

$$T(p) = \frac{X_o}{F_i}(p) = \frac{1}{M} \cdot \frac{1}{p(p+C/M)}$$

giving the p-plane pattern of Fig. 8.

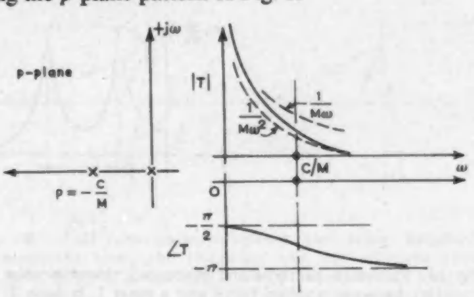

Fig. 8 Transfer between applied force and mass displacement for system of Fig. 7

The pattern contains a pole at the origin, showing that the displacement is theoretically infinite as the frequency approaches zero, and decreases inversely with frequency for low frequencies where $\omega < C/M$. For higher frequencies the pole on the negative real axis becomes effective and the displacement will decrease inversely with the square of the frequency. The phase angle is initially $-\pi/2$ and finally approaches $-\pi$.

The transfer for the extension of the spring $(x_i - x_o)$ for an input displacement x_i can be obtained from the transfer

$$\frac{X_o}{X_i}(p) = \frac{1}{(p/\omega_n)^2+2\zeta p/\omega_n+1}$$

which gives

$$\begin{aligned}(X_i-X_o) &= X_i(1-1/((p/\omega_n)^2+2\zeta(p/\omega_n)+1)) \\ &= X_i((p/\omega_n)^2+2\zeta(p/\omega_n))/((p/\omega_n)^2+2\zeta(p/\omega_n)+1)\end{aligned}$$

or

$$\begin{aligned}T(p) &= (X_i-X_o)/X_i \\ &= (p/\omega_n)((p/\omega_n)+2\zeta)/((p/\omega_n)^2+2\zeta(p/\omega_n)+1)\end{aligned}$$

giving a (p/ω_n)-plane pattern for small damping as in Fig. 9. For low frequencies the extension is small, increasing with frequency and passing through a peak in the vicinity of the natural frequency. The extension finally approaches a steady value at high frequencies, this corresponding to a substantially stationary mass.

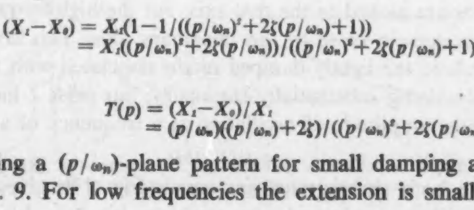

Fig. 9 Transfer between applied force and spring extension for system of Fig. 7

(c) Twin-tee network

For the twin-tee network in Fig. 10, the voltage transfer,

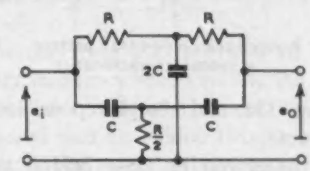

Fig. 10 Twin-tee network

with the relative values of C, R, indicated, becomes

$$T(p) = \frac{E_o}{E_i}(p) = \frac{1+(p\tau)^2}{(p\tau)^2+4p\tau+1}$$

having zeros at $\pm j1$ in the $p\tau$ plane, and poles at $-2 \pm \sqrt{3}$, as in Fig. 11a.

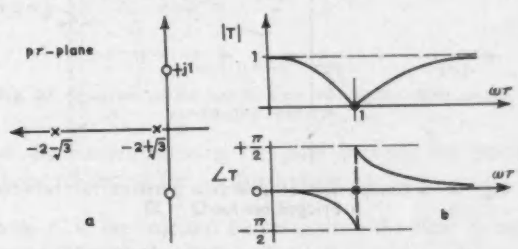

Fig. 11 a Twin-tee pole-zero pattern. b Frequency response characteristics

The general form of the frequency characteristic is shown in Fig. 11b, where zeros on the imaginary axis imply that there is no transmission for the frequency $\omega = 1/\tau$.

(d) Bridged-tee network

An alternative rejection network is the bridged tee of Fig. 12,

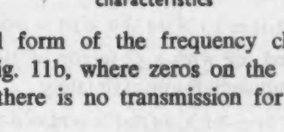

Fig. 12 Bridged-tee network

which yields the voltage transfer function

$$\frac{E_o}{E_i}(p) = \frac{(p/\omega_n)^2+1}{(p/\omega_n)^2+2p/\omega_n Q+1}$$

where $\omega_n^2 = 2/LC$, $Q = \omega_n L/R_1$ and R_2 is adjusted so that

$$R_2 = (\omega_n L)^2/4R_1$$

The transfer has zeros on the imaginary axis in the (p/ω_n) plane at $\pm j1$.

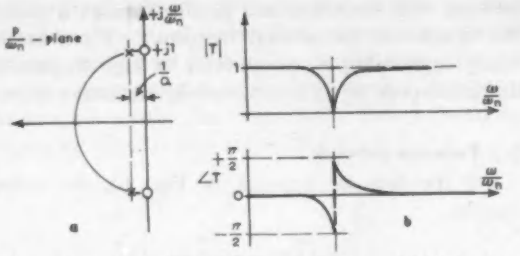

Fig. 13 a Bridged-tee pole-zero pattern. b frequency response characteristics

shown in Fig. 13a, and complex poles located on the unit radius circle.

Since the poles can be close behind the zeros for large values of Q, the rejection provided by the bridged tee is much sharper than for the twin tee, and the patterns of Fig. 14 enable one to make a quick comparison of sharpness. At a frequency 10% removed

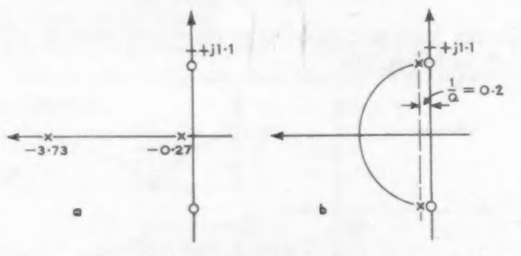

Fig. 14 a Comparison of pole-zero patterns for twin-tee b Bridged tee for Q = 10

from the rejection the twin-tee transfer can be quickly approximated as

$$T(j1{\cdot}1) \simeq 2{\cdot}1 \times 0{\cdot}1/3{\cdot}9 \times 1{\cdot}1 = 0{\cdot}049$$

For the bridged tee with a Q factor of 10, the transfer at the same frequency is approximately

$$T(j1{\cdot}1) \simeq 2{\cdot}1 \times 0{\cdot}1/2{\cdot}1 \times 0{\cdot}14 = 0{\cdot}707$$

being about fourteen times better than the twin tee.

(e) Coupled spring-mass system

The coupled spring-mass system of Fig. 15, where masses and spring-rates are assumed to be the same, yields the transfer between a force applied to mass 1

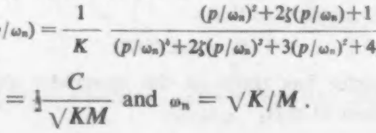

Fig. 15 Coupled spring-mass system

and the displacement of the same mass

$$\frac{X_1}{F_1}(p) = \frac{Mp^2+Cp+K}{M^2p^4+MCp^3+3MKp^2+2KCp+K^2}$$

which may be written as

$$\frac{X_1}{F_1}(p/\omega_n) = \frac{1}{K}\,\frac{(p/\omega_n)^2+2\zeta(p/\omega_n)+1}{(p/\omega_n)^4+2\zeta(p/\omega_n)^3+3(p/\omega_n)^2+4\zeta(p/\omega_n)+1}$$

where $\zeta = \frac{1}{2}\dfrac{C}{\sqrt{KM}}$ and $\omega_n = \sqrt{K/M}$.

In addition the transfer to the second mass becomes

$$\frac{X_2}{F_1}(p/\omega_n) = \frac{1/K}{(p/\omega_n)^4+2\zeta(p/\omega_n)^3+3(p/\omega_n)^2+4\zeta(p/\omega_n)+1}$$

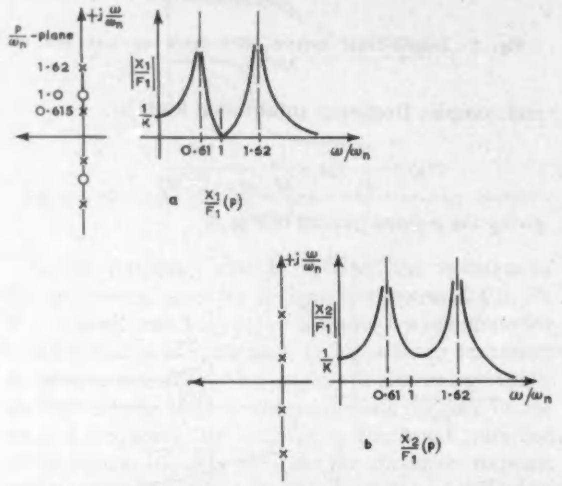

Fig. 16 Pole-zero patterns and frequency characteristics for transfers between applied force and a mass 1, b mass 2, for the system of Fig. 15 when $\zeta = 0$

If the damping is zero, the system becomes an undamped vibration absorber(3), with zeros in the transfer to x_1 on the imaginary axis at $(p/\omega_n) = \pm j1$, as in Fig. 16a. The latter shows that there is no displacement of mass 1 for a force applied with this frequency. These zeros are absent from the transfer to x_2, Fig. 16b, which has a finite displacement at this frequency. Both transfers have poles on the imaginary axis at

$$(p/\omega_n) = \pm j1{\cdot}62;\ \pm j0{\cdot}615$$

corresponding to the natural modes of the system.

If damping is introduced, all poles and zeros move back from the imaginary axis, giving a bounded frequency response as in Fig. 17a, which gives approximate positions and frequency response for $\zeta = 0{\cdot}2$. If the damping is increased still further, the low-frequency poles are moved to the real axis, but the high-frequency poles remain close to the imaginary axis. This corresponds to the lightly damped mode associated with mass 2 remaining substantially stationary, but mass 1 having a large amplitude of oscillation at a frequency of about

$$\omega = \sqrt{(2K/M)}$$

since both spring rates are equal. Fig. 17b gives the approximate pole and zero positions for $\zeta = 1{\cdot}0$.

Fig. 17 Pole-zero patterns for system of Fig. 15 with varying dampings: a $\zeta = 0{\cdot}2$, b $\zeta = 1{\cdot}0$

Non-minimum-phase-shift networks

In the previous examples, all poles and zeros have been restricted to the left half plane. This restriction is essential for the poles of a stable function, but zeros may be located in the right half plane.

Functions with zeros in the right half plane are of *non-minimum* phase shift, since a given amplitude characteristic may be obtained with minimum phase shift with zeros in the left half plane. The two patterns shown in Fig. 18a, b, will have the same amplitude

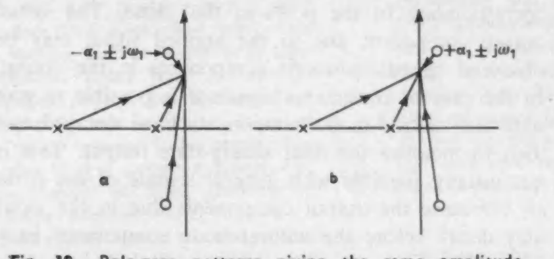

Fig. 18 Pole-zero patterns giving the same amplitude characteristic along the imaginary axis but different phase characteristics: a minimum phase, b non-minimum phase

characteristic along the imaginary axis, but different phase characteristics.

Patterns with poles in the left half plane and an image pattern of zeros in the right half constitute *all-pass* units in that the amplitude characteristic is independent of frequency, owing to the symmetry of the pattern, but the phase angle changes continuously with frequency. For the pattern shown in Fig. 19, the phase will be given by

$$\angle T = -\theta_1 + (\pi - \theta_1) - \theta_2 + (\pi - \theta_2)$$
$$= -2(\theta_1 + \theta_2)$$

and the phase will lag from $0 \rightarrow -2\pi$ as the frequency changes $0 < \omega < \infty$, but $|T|$ will remain constant.

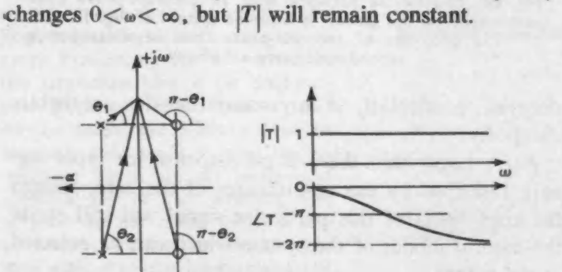

Fig. 19 Symmetric pattern yielding a constant amplitude along the imaginary axis but varying phase

LOGARITHMIC REPRESENTATION

Since considerable multiplication and division is involved in evaluating a complicated function, a logarithmic form can be used. The normal relation for the logarithm of a complex number

$$\log(p - p_a) = \log|p - p_a| + j\angle(p - p_a)$$

applied to a general transfer

$$T(p) = K\frac{(p - p_a)(p - p_b)\ldots}{(p - p_1)(p - p_2)\ldots}$$

where K is a constant multiplier, gives

$$\log T(p) = \log|T(p)| + j\angle T(p) = \log K + \log|p - p_a| + \log|p - p_b| + \ldots$$
$$- (\log|p - p_1| + \log|p - p_2| + \ldots)$$
$$+ j[\angle(p - p_a) + \angle(p - p_b) + \ldots$$
$$- (\angle(p - p_1) + \angle(p - p_2) + \ldots)]$$

The phase of the logarithmic function is obtained by angle summation, and the magnitude by distance logarithm summation. Various computing devices based on this principle, such as the *spirule* (*4*), have been devised, and digital computers have also been used for pattern investigation (*5*).

The logarithmic form also provides an analogy between complex frequency functions and the current flow and potential distribution in a conducting medium. If current is passed into an infinite two-dimensional conducting medium, the potential between two points *a*, *b* where *a* is the reference point (Fig. 20) is proportional to the logarithm of the distance ratio

$$e_{ba} \propto \log(D_1/d_1) = \log D_1 - \log d_1$$

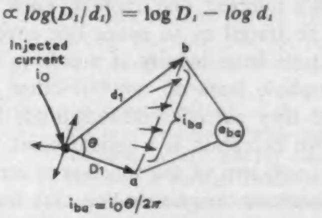

Fig. 20 Injection of current into an infinite two-dimensional conducting medium

and the current crossing the path between the points will be related to the enclosed angle by

$$i_{ba} = i_0\theta/2\pi$$

where i_0 is the injected current, since the flow is uniformly distributed radially.

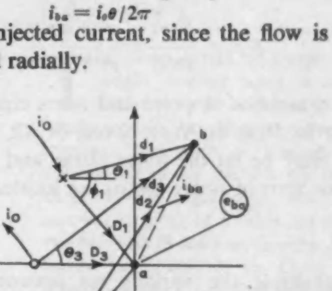

Fig. 21 Basis of analogy between two-dimensional current flow and complex frequency functions

If current is introduced at a number of *sources* and removed at a number of *sinks* (there being at infinity a number of sources or sinks equal to the difference in number on the plane) the potential obtained with respect to a reference point as in Fig. 21, is given by

$$e_{ba} \propto \log D_1 + \log D_2 - \log D_3 - \log d_1 - \log d_2 + \log d_3$$

for the case of two sources and one sink. The current flow across the path between the points will be

$$i_{ba} = (i_0/2\pi)(\phi_1 + \phi_2 - \theta_3)$$

which can easily be shown to be

$$i_{ba} = (i_0/2\pi)(\theta_1 + \theta_2 - \theta_3)$$

Hence, if sources and sinks are identified with poles and zeros, an analogy can be established between potential distribution and logarithm of magnitude, and between current and phase angle, since the forms of the relevant expressions are similar.

This analogy—the *potential analogy*—has been extensively used with electrolytes and other conducting media, for investigations in network synthesis, closed-loop system analysis and many other problems.*

CONCLUSION

The examples considered have illustrated the application of complex frequency analysis to various systems, and the development of frequency response characteristics by examination of the constant-phase-and-magnitude pattern along the imaginary axis.

Constant-magnitude lines are closed on themselves and do not intersect one another. Each constant-phase line can be traced as an *entire* line covering all values of magnitude from infinity at a pole to zero at a zero. Constant-phase lines do not cut other constant-phase lines, and they cut constant-magnitude lines perpendicularly. An exception is a saddle point, where the differential coefficient of the function is zero. At a saddle point a constant magnitude-line cuts itself, and entire constant-phase lines of the same value touch; in addition, the perpendicular intersection of phase and magnitude lines fails.

Functions which are ratios of polynomials

$$F(p) = \frac{N(p)}{D(p)} = \frac{p^m + a_1 p^{(m-1)} + \ldots}{p^n + b_1 p^{(n-1)} + \ldots}$$

have a number of poles and zeros equal to the highest power in $D(p)$ or $N(p)$. Some, or all, of the poles and zeros may be on the finite plane, and the remainder, a pole or zero of order $(m-n)$ are located at infinity since

$$F(\infty) = p^m / p^n$$

For example the various tee networks already considered have two poles and two zeros, all of which are located on the plane. Hence all constant-phase lines are completely terminated on the plane. The form of the 0° and 180° lines for the twin tee are shown in Fig. 22a, together with the general shape of the constant-magnitude line passing through the saddle points at $p = +1, -1$. There are two entire 0° and 180° lines, though one 0° line passes through infinity, and the unit-magnitude line is also completed through infinity.

For the case of the coupled spring-mass system of Fig. 15, there are two zeros at infinity; hence two sets of constant-phase lines terminate at infinity. The general form of the 0° and 180° lines for $\zeta = 1$, giving a second-order zero on the negative real axis, is shown in Fig. 22b. A pair of 0° lines pass to infinity along the real axis, and a pair of 180° lines pass to infinity along the imaginary axis.

*See general references.

Along the imaginary axis a pole-zero pattern defines a frequency response characteristic for signals of the form $e^{j\omega t}$ corresponding to constant amplitude oscillations. This characteristic can be measured practically by normal frequency response measurements, if the pattern is physically realizable as a system. The pattern also defines other frequency response characteristics for general signals of the form $e^{(\alpha+j\omega)t}$. These characteristics cannot normally be measured because the test signal must be applied at some instant, and the application of the signal excites the natural modes of the system corresponding to the poles in the plane. The actual output component due to the applied signal may be obscured by natural-mode components in the output. In the case of continuous signals it is possible to wait until the natural-mode components have decayed and then to measure the final steady-state output. This is not usually possible with general signals of the form $e^{(\alpha+j\omega)t}$ since the output components due to the input may decay before the natural-mode components have

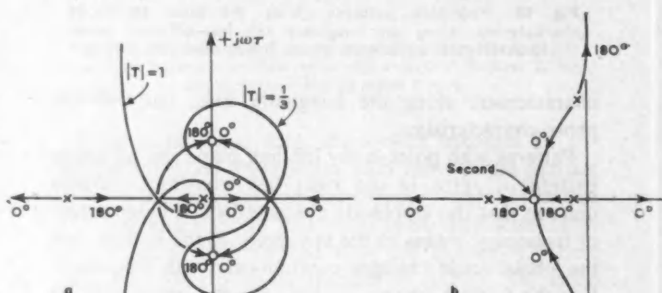

Fig. 22 a Twin-tee network with all constant-phase lines terminated on the plane. b Coupled system of Fig. 15 with $\zeta = 1$; two sets of constant-phase lines terminate on a second-order zero at infinity

decayed, particularly if any natural modes are lightly damped.

Zeros imply that there is no response for input signals described by the co-ordinates of the zero, though the application of this particular signal will still excite the natural modes of the system which can be detected at the output.

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General

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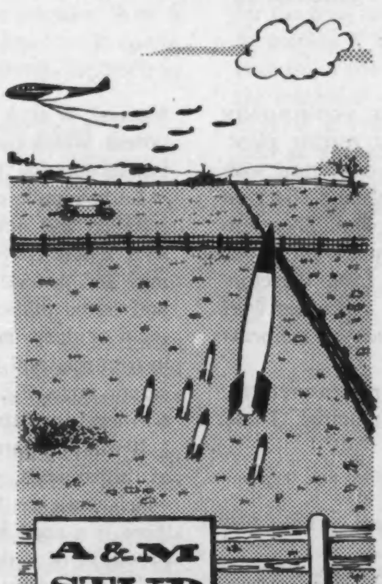
Pick-off

by 'UNCONTROLLED'

In the old days, when engineers wrought in cast iron and decorated their products with flowery borders, they often spent much time in looking for the solutions to their problems. Today they use smooth-surfaced plastics and the speed of progress is vastly greater. Few of us realize how much this acceleration is due to that unknown genius who first thought of fitting problems to existing solutions; after that it is child's play to design a customer who will fit a product. Take certain large companies in the data processing business, for instance, who find the supplying of card punches and peripheral etceteras so profitable that they have designed the written-language problem right out of existence. They dismiss all this talk about a common tongue for man and machine: '*Educate* your customers,' they say; 'a card- punch in every home! Write your letters on magnetic tape!' Which is rather like solving the problem of translating French by telling all Frenchmen to jolly-well-learn English.

Other companies do better and offer a dual-purpose typewriter or accounting machine—they would deal with French translations by grafting an English-speaking Siamese twin on to every Frenchman. An adaptation of this interesting idea is the dual-purpose document, which can be read by the naked eye while a code or magnetic strip on it is read by the machine. These are all really neat modifications of the problem, and at least do not claim to have any connexion with reading; but the systems offered to the banks claim just that. Not only do they use dual-purpose documents, they use dual-purpose characters as well. So we are still stuck with our Siamese twin (because none of these characters can be printed without special equipment), but now both twins are talking at once, one in English and the other in French. Finally we have the rather costly techniques for reading 'normal' characters. One solution is so clever that the problem has hardly had to be modified at all. The only requirement is that the customer confine himself to printed characters of a certain kind, produced by certain specified equipment, and needing not much more than a digital computer for interpretation. Thus, if the Frenchman will limit himself to a few basic words of his language, and hire an elocutionist to pronounce them, he need no longer suffer his Siamese twin. So why should anybody persevere in the old-fashioned attempt to design an input device that can read ordinary documents? Mind is so much more easily moulded than matter.

Sir Roy Dobson was quoted as the authority by Michael James last October when he wrote in *Control* that 'out of the breeding ground of aircraft and missile development may come the equipment and ideas that will foster and advance automation systems in a much wider range of industry. I wonder whether either James



or Sir Roy foresaw this one: Fairbanks, Morse & Co. tell me that they have engineered for the Mid-west Livestock Commission in Nevada a system that incorporates several features borrowed from the guided-missile industry. There is a device that flashes the weight of animals on to a 'tote' board as they enter the auction ring, and bidders see not only the individual weights but also the automatically computed average of the lot. I understand that the prototype system is being closely studied by experts on both sides of the Atlantic. Perhaps all that money spent on missiles was not wasted after all.

Engaged a while ago in the thankless task of proof-reading, I found a courteous little note attached to the author's corrected galleys. 'I have taken the liberty of correcting certain items of American spelling . . .', he wrote: 'If, on the other hand, it is the policy of your publication to employ American spelling . . . I shall of course raise no objection'. This lifted my eyebrows a bit, for *Control's* style is founded on the rock of the Oxford Dictionary. Where the O.D. has not caught up with modern technical words we turn to British Standards. I suppose that the French spelling of the suffix *-ize* has now become so wide-spread that the older version has for some people acquired a foreign (and more particularly American) look. Where we do look rather American is in writing *program* without the gratuitous *me* on the end. O.D. admits that the tailpiece is 'now usu.' but does not approve of it, and B.S. terminology is also against it.

The simplicities of simple harmonic motion were first revealed to me in a poky little lecture room, too long ago for my comfort. The voice of wisdom was just audible above the squawk of the chalk on the blackboard, and I remember its story of a 'rotating radius vector' with a shadow dancing backwards and forwards in s.h.m. The interesting thing was that this mathematician's fancy proved to be only one instance of the motion, and that various other things like tides and pendulums turned out to behave in an equally 'simple' way. The voice in the lecture room explained that, because so many different kinds of oscillator followed the beat of this same baton, the speed of the 'rotating radius vector' was a handy thing to know. Called the 'pulsatance', the speed turned out to be closely related to that other useful figure, 'frequency'.

Nowadays, in the general detestation for π and all its multiples, pulsatances have been spirited away and we hear only of frequencies. Thus is the flickering shadow merged with that which casts it, and we are more in the dark than ever. Am I just pining uselessly for my youth, or is there really a case for restoring the old term and so avoiding ambiguity?

CONTROLLING NUCLEAR POWER—4

As well as having to make all the measurements usual in power stations, the operator of nuclear plant must watch a number of new physical quantities to keep up both efficiency and safety

Instrumentation of nuclear power stations

by **DENIS TAYLOR**, M.SC., PH.D., M.I.E.E., F.INST.P.
Plessey Nucleonics Ltd

THIS ARTICLE GIVES A SURVEY OF THE INSTRUMENTS needed for the operation of a nuclear reactor plant. The majority of these instruments are concerned with reactor power, its measurement, control, and effect on the temperature of components and coolant. There are two main groups of instruments associated with power measurement, namely those operated from detectors sensitive to the neutron flux, and those concerned with physical measurements of quantities such as temperature and coolant flow.

Apart from those needed for power measurement, various other types of instrument are required. These are:

1 Instruments for the measurement of neutron flux distribution throughout the reactor core

2 Instruments for the detection and location of burst fuel element cans

3 'Health' instruments, which are for the measurement of radiation levels in the working space around the reactor and in the general locality.

Instruments in the first category are required to allow the fuel-element loading to be changed periodically to ensure the greatest possible reliability and efficient operation of the reactor.

When the fuel is incompatible chemically with the coolant, it is vital that faults in the fuel containers be detected and located rapidly if damage or serious contamination of the reactor and coolant are to be avoided. Special instrumentation is necessary to ensure early warning of such failures, and in practice an elaborate system, which can be an appreciable part of the whole instrumentation, is necessary.

Large numbers of health monitoring instruments, both installed and portable, are required for use at reactor sites. These cover the monitoring of the reactor buildings and general site area, the monitoring of gaseous and liquid effluents, the monitoring of personnel and their clothing in the change rooms. There are also instruments and control apparatus to govern access to certain areas, e.g. fuel-element loading bays, if the radiation levels are above what is known to be safe.

It will be appreciated that there is a great complexity of instruments, and large quantities of information which must be logged or recorded. This means that there is a need in large nuclear power stations for the provision of a data-handling system which can watch the measurements made by all the many instruments, and call the attention of the control engineer to any abnormality in the readings so that corrective action may be taken. In some cases this can be done automatically, but in other cases manual action is appropriate.

Power measurements

Neutron flux measurement gives a direct indication of the fission rate, and therefore of the operating power of the reactor. This is one of the most significant of the nuclear measurements. During the starting-up of a reac-

tor it is essential that the reactivity addition, by the withdrawal of the neutron-absorbing control rods, should not take place too rapidly. It is therefore necessary also to monitor a parameter which indicates the rate of change of power with time. The parameter usually chosen is the **doubling time,** which is the time for the neutron flux, and therefore the power level, to double itself given the existing reactivity.

The basic neutron-flux-measuring system therefore comprises a radiation detector sensitive to neutrons, an amplifier usually providing an output proportional to the logarithm of the power (log *P*), a power indicator (usually graduated to cover many decades of power), a circuit differentiating the logarithm of the power level (i.e. giving $\frac{d}{dt}(\log P) = \frac{1}{P}\frac{dP}{dt}$ which is a measure of the reactivity*), followed by a reactivity or doubling-time meter. It is also usual to provide trigger circuits which operate automatically to shut the reactor down (or to reduce power considerably) if either the measured power rises above a certain preset level, or if the doubling time falls below a value which is known to be safe. This is shown in Fig. 1. Note that in this case an ionization chamber is used as the neutron-sensitive detector.

The operating range from shut-down to full power varies with the type of reactor and the duration of the shut-down, but is rarely less than six decades. With a heavy-water-moderated reactor which has been in operation for some time and is then shut down, the neutron

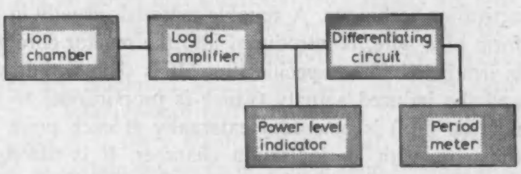


Fig. 1 Power-measuring equipment

flux takes several days to fall to 10^{-8} of its operating value. This high shut-down level is due to delayed neutron emitters which are produced in the heavy water by the gamma-active fission-products of the fuel.

It follows that, with a reactor of this type, power indication over six decades usually suffices. With graphite-moderated reactors, on the other hand, the shut-down flux may fall to about 10^{-10} of the initial operating level, which demands instrumentation over a considerably wider range. However, difficulties with instrumentation are avoided in the latter case by placing **neutron sources** in the core of the reactor. By this means the instrument range of a graphite-moderated reactor can be reduced to about seven decades with only a small loss of reactivity, and this expedient has been used (*1*) in all the Calder-Hall-type reactors. The usual kind of source depends on the (γ, *n*) reaction.* Sodium (Na^{24}) and antimony (Sb^{124}) have been used as a source of γ-rays, which, on bombarding beryllium produce neutrons. This is an attractive technique† because it results in a self-sustaining system. The sources become active whilst

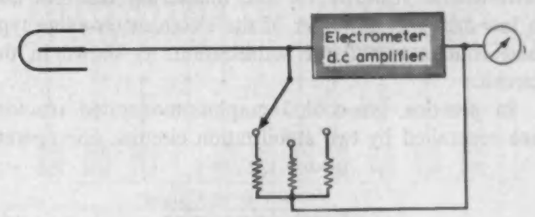


Fig. 2 D.C. linear channel

the reactor is operating and raise the shut-down level when the reactor is off. It is however necessary to decide the expected duration of the normal shut-down to choose the best artificial source.

Sodium, usually as sodium carbonate, has the highest neutron emission for a given reactivity loss, but has a half-life of only 14·8 hours. Antimony is the next best material; it has a half-life of about sixty days, but a neutron emission when used with beryllium of only about one-sixth that of sodium carbonate.

The circuit shown in Fig. 1 is employed for measuring the power from shut-down to operating level, but for the final adjustment of the operating level it is usual to employ a linear-range system as shown in Fig. 2, because of the greater precision obtainable. In this case the ionization current from the detector is employed to develop a voltage across the measuring resistor. It is also an advantage to employ the circuit shown in Fig. 3, which permits the actual operating power to be compared with the demanded power, the difference being presented on a centre-zero meter as an error signal. In this case the demanded power may be varied by changing the reference voltage, or the reference voltage may be fixed and the d.c. amplifier measuring resistor

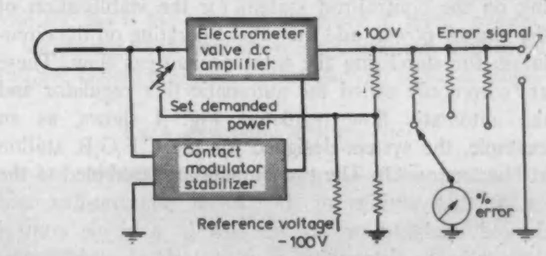


Fig. 3 Drift channel

changed. Both methods are in use, the former giving an absolute and the latter a percentage error signal. This measuring channel is used either manually or automatically to regulate the reactor power, and consequently it should be both accurate and stable. It should be

* It follows from the approximate equation $P = P_0 \exp(t/T)$, which is valid after the initial transient has died out (*T* is called the *reactor period*) that $\frac{d}{dt}(\log P) = 1/T$.

* The notation (γ, *n*) implies that the nuclear reaction has been caused by γ-radiation, with neutron emission as the effect. A γ-photon has been absorbed by the nucleus and a neutron has been expelled.—EDITOR.

† See reference 2 for fuller details.

noted that the use of an error-signal amplifier for automatic power regulation necessitates a short response time.

This requirement for a high band-width, together with good accuracy and stability, leads to the choice of wire-wound resistors for the measuring resistors and a low-drift d.c. amplifier of the electrometer-valve type and contact modulator stabilization, as shown in the circuit.

In practice, gas-cooled graphite-moderated reactors are controlled by two stabilization circuits, one operating on the control-rod system for the stabilization of the reactor power, and the other operating on the circulators for stabilizing the total coolant-gas flow. These are commonly called the automatic flux regulator and the automatic flow regulator. Fig. 4 shows, as an example, the system designed for the C.E.G.B. station at Hunterston (3). The two circuits are combined to the extent that settings of the desired neutron-flux and desired coolant-flow are coupled in a single control (known as the automatic power control) which is motorized. This limits the range of change of power, and is set by the reactor operator at his control desk. In this case a constant ratio is maintained between the desired neutron-flux and the desired coolant-flow.

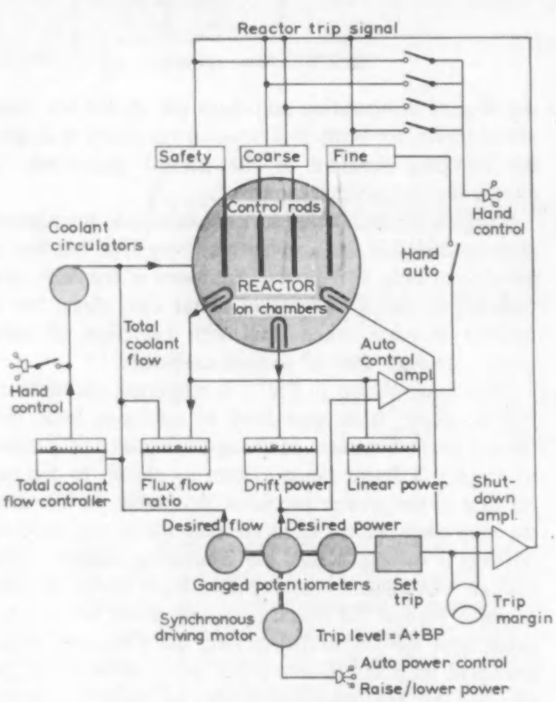


Fig. 4 Reactor control system

In most of the reactors being built, or already commissioned, it has been found convenient to employ neutron-sensitive detectors sensitive to thermal neutrons.

These have been fully described in the literature (4, 5, 6). The siting of these detectors is of some importance. They must be placed in a position where they will give a good output current, and yet not be in such a high flux that they deteriorate rapidly under it. They must also be placed in a position giving good discrimination between neutron flux and γ-radiation from the reactor. This requires that they be kept away from reactor structural material such as steel, which may remain γ-active after the reactor has been shut down. They must also be sited so that the sample of neutron flux which they 'see' is representative of the total fission rate of the reactor, and is not seriously affected by perturbations in flux distribution by movement of the control rods.

Temperature measurements

The measurement of temperatures in the reactor of the fuel elements, the graphite moderator, and the coolant, is of considerable importance. In the present gas-cooled reactors being built in this country it has been found convenient to employ thermocouples. For the measurement of temperatures in the gas ducts a response time of ten seconds is required, and this can be met conveniently with thermocouples.

Neutron flux distribution measurements

It is periodically necessary to measure the neutron flux distribution across the core of the reactor. This is necessary, for example, to ensure that the fuel-element loading has been adjusted to give the flux distribution necessary for efficient operation and efficient use of the fuel.

The method usually employed depends on a neutron-activation technique. A suitable material, usually in the form of a wire, is introduced into the reactor core and is irradiated for a specific time. It is then withdrawn, and the induced activity (which is proportional to the neutron flux) is measured externally at each point on the wire, with an ionization chamber. It is therefore possible to determine the neutron flux distribution for each channel in which the wire is placed. This method has been used with success at Calder Hall and Chapelcross, and is to be used in the first-round C.E.G.B. stations.

Recently a new method has been proposed (7) using a small neutron-sensitive ionization chamber which is lowered through the core of the reactor on the end of a suitable high-temperature flexible cable from a winding head installed in a stand-pipe on the reactor cap. The output of the ionization chamber is passed from the winding head to a chart recorder. In a practical system a number of winding heads is installed across the reactor cap, and each head is operated in turn from a control position. Ionization chambers have been designed which can operate at temperatures in excess of 500°C. The design of the winding head varies according to the type of reactor, but in most cases it is usual to provide for both automatic and manual operation, and to fit both mechanical and electrical devices for indicating the wire position, as well as alarm and safety circuits which will operate in the case of mal-operation.

Detection of burst fuel-element cans

Various systems can be used (*8, 9*) for the detection of burst fuel-element cans, but the method which has proved most popular and has been generally adopted for gas-cooled power reactors is that used at Calder Hall. This system depends on the detection of gaseous fission-products which decay into active solids. A number of these gaseous-fission products decay by emitting β-particles from their nuclei and becoming charged particulates which may be attracted to a negatively charged electrode.

The gas is first filtered and then passed into a **precipitation chamber** where the solid daughter products of the decayed fission products are deposited on a negatively charged wire electrode. It is usual to employ a moving wire. After a period of time in the precipitation chamber this wire moves into a detection apparatus where the active products deposited on the wire are sensed by a scintillation counter. In the actual system a sample tube is attached to each channel-top and is brought out through the pressure vessel and biological shield. Here the tubes are parallelled in groups of four and are then passed to a bank of rotary selector valves and thence to precipitation-detection apparatus of the type already described. Thereafter the gas from all the channels passes to the main coolant circuit by an auxiliary compressor. Fig. 5 is a schematic diagram of the sampling system, and Fig. 6 shows a precipitator of the type being manufactured for use at the Hinkley Point and Latina Stations.

It will be noted that additional precipitators are provided for bulk monitoring. This is necessary because, referring to the Calder installation, 54-way selector valves are employed with a sampling time for each group of four pipes of half a minute. It follows that a complete scan takes about half an hour, and as this might in certain instances be a long time to wait, it is useful to have continuous monitoring facilities available with the bulk monitoring system even without location, so that if a serious fault arises it can be noted immediately.

The selection system described (see Fig. 5) allows detection of a fault to a group of four channels. It is then necessary to operate manual cocks in the paralleling system to determine which channel in the group of four is the faulty one.

Reliability and safety

The safety of a reactor is a subject of very considerable importance, and a large part of the instrumentation is necessary to ensure that neither an error on the operator's part, nor the occurrence of a fault in some component, can bring about a situation which might result in the reactor getting out of control and damaging itself. In power reactors particularly, protection is necessary against the effects of excessive neutron flux, abnormal temperature gradients and high temperature.

In starting and operating a nuclear reactor it is essential that the necessary control should be carried out according to a pre-arranged sequence. It is then the function of the control interlock circuits (sometimes called the 'safety' circuits) to ensure that the correct sequence is followed and that it is not violated in any way. In addition to the normal interlocks there are other 'conditional' interlocks which govern operations during, say, a maintenance period.

Nuclear power stations employ a relatively large amount of electronic equipment and the highest reliability is essential. Marginal testing and other 'preventive' maintenance can pay real dividends here in providing, or assisting to provide, trouble-free operation of electronic equipment; but even so, faults do occur, and therefore methods have to be devised so that a fault in, say, a component does not shut the reactor down unnecessarily. One method which has been used with success is the so-called 'two out of three' system, in which, e.g., the shut-down amplifiers are triplicated and the system designed so that two out of three ampli-

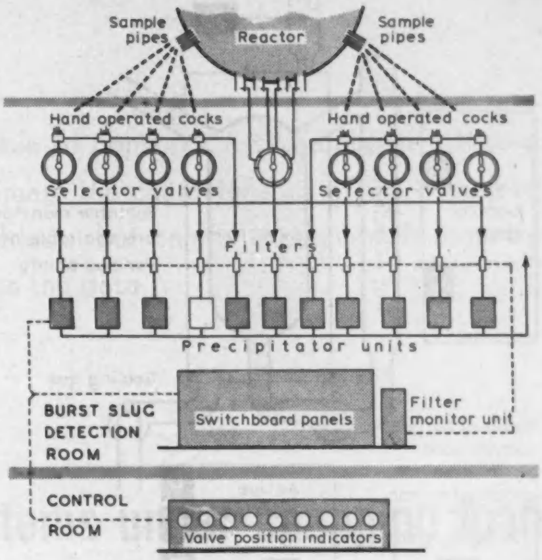
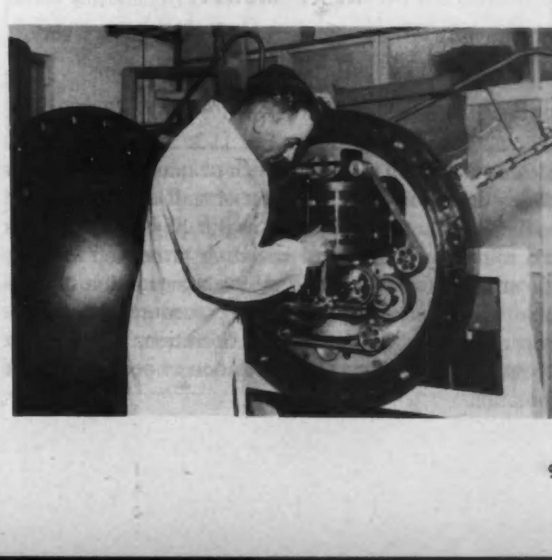


Fig. 5 Arrangement of sampling system

Fig. 6 Adjustment of precipitator



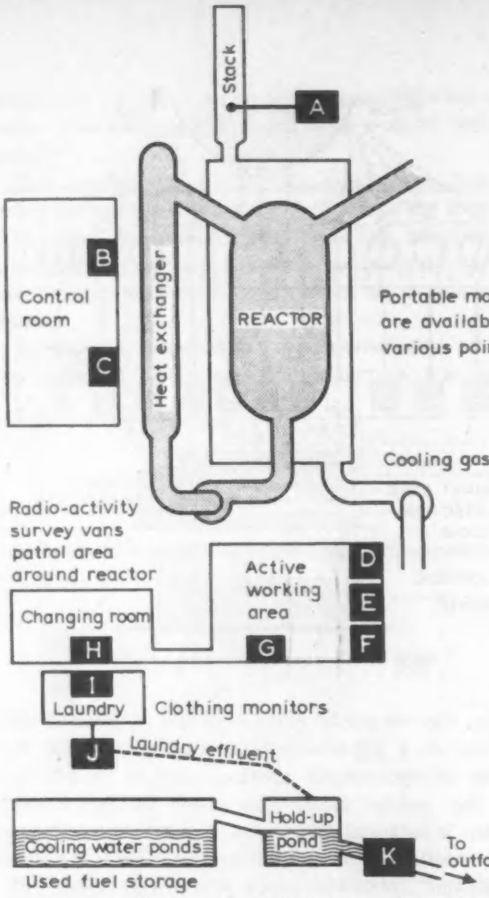


Fig. 7 'Health physics' monitoring around a reactor. A—stack-gas monitor. B—dose-rate monitor. C—total-dose monitor. D—dose-rate monitor. E—total-dose monitor. F—air monitor. G—portable monitor. H—hands and clothes monitor. I—contamination monitor. J—laundry effluent monitor. K—effluent monitor

fiers have to indicate the dangerous condition before the reactor is shut-down.

Health instruments

It has been said that **health physics** is a mis-named subject, for it is concerned neither with health nor with physics. Nevertheless, an attempt has been made to define it, and according to the American National

NEXT MONTH

The fifth article in the series will be 'Stability considerations in power-reactor systems' by **R. I. Vaughan,** *U.K. Atomic Energy Authority.*

Research Council it is that branch of radiological physics which deals with the protection of staff against ionizing radiation. The work of the 'health physicist' includes the routine procedures of radiation protection surveys, air and personnel monitoring, recommendation of suitable protection equipment and procedure, determination of acceptable standards of operation, and solution of problems relating to the protection of persons against radiation.

Large numbers of health monitoring instruments (*10*) are required for use at reactor sites. As yet no complete agreement exists as to what is required but the following is typical:

INSTRUMENT	PURPOSE
1. Installed and portable dose-rate monitors for γ-, slow-neutron and fast-neutron radiation.	Monitoring of reactor buildings and general site area.
2. Portable accumulated dose-meters.	Monitoring of dose received by personnel in reactor buildings and cooling pond area.
3. Air sampling equipment.	Monitoring of air in area.
4. Hand and clothing monitors.	Monitoring of personnel and their clothing in change rooms.
5. Clothing monitors.	Monitoring of clothing, etc., in active laundry.
6. General-purpose contamination monitors.	Monitoring of equipment, benches, floor, etc., in reactor buildings, pond area, etc.
7. Liquid-effluent monitors.	Monitoring of liquid effluents from effluent farm, etc.
8. Gaseous-effluent monitors (sometimes called stack monitors).	Monitoring of gaseous effluents from reactor stack.
9. Apparatus for radio-active assay, comprising Geiger counters, scintillation counters, scalers, power units, etc.	For use in 'health physics' laboratories for checking the activity of biological samples, smear-test samples, etc.
10. Survey vans fitted with apparatus for general activity measurements and dose-rate measurements.	Monitoring in site area and in the vicinity of site.

Fig. 7 summarizes these various requirements.

Special problems

With large gas-cooled reactors, spatial instabilities can occur, and it is therefore necessary to consider providing control systems which operate independently on different parts of the reactor core. Thus, for some of the new reactors under construction, more instrumentation is provided so that sectorial control is possible to deal with radial-mode instabilities (*11*). This duplication of the control gear may need to be extended further. It is thus clear that there is a real need for 'in-pile' detectors, so that the neutron flux at specific points in the reactor core can be measured specifically, instead of being deduced from measurements made outside the core. This matter has been discussed recently (*12*).

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PART 3

It should be possible to construct a comprehensive theory from which to estimate the characteristics of the complete water-level control loop, but careful experiment is urgently needed to establish the data

Boiler feed discharge systems under changing load

by **A. J. MORTON,** M.SC., A.M.I.MECH.E.
Central Electricity Generating Board

Design without stability or response calculations is becoming inadequate. In Part 1 of this article (Nov. 1960) we made certain basic assumptions before considering the discharge system in detail. Last month, in Part 2, we discussed the characteristic equations for the combined pump and system. We then began an account of the response of flow rate to feed-regulator movement, and this is continued below

Systems with governed pumps

Equations 17, 20 and 23 are all of the form

$$[(1+T_1\mathrm{D})(1+T_2\mathrm{D})]Q=C+C_1(1+T_3\mathrm{D})y \qquad (29)$$

It is theoretically possible for T_1 and T_2 to be complex, but this appears unusual for turbo-driven feed pumps of normal design, judging from the very limited number of cases so far examined.

Following a sudden unit opening of the regulating valve, the transform of that part of the flow rate which is affected is obtained by multiplying the transfer function $C_1(1+T_3s)/(1+T_1s)(1+T_2s)$ by the unit step-function transform $1/s$, giving

$$\frac{C_1(1+T_3s)}{s(1+T_1s)(1+T_2s)} = C_1\left\{\frac{1}{s}-\frac{(T_1-T_3)}{(T_1-T_2)}\cdot\frac{1}{(1/T_1+s)}-\frac{(T_3-T_2)}{(T_1-T_3)}\cdot\frac{1}{(1/T_2+s)}\right\} \qquad (30)$$

which on inverse transformation gives

$$Q=C+C_1\left\{1-\frac{(T_1-T_3)}{(T_1-T_2)}e^{-t/T_1}-\frac{(T_3-T_2)}{(T_1-T_2)}e^{-t/T_2}\right\} \qquad (31)$$

after adding in the constant part C of the flow rate.

The shape of the response curve obtained by plotting Q against t varies greatly according to the relative values of T_1, T_2 and T_3, but in all cases Q approaches its final equilibrium value of $C + C_1$ without oscillation. Typical numerical values for the time constants are estimated later. In a well-designed system, the exponential terms will decay so quickly that the delay in response of the flow rate will be barely perceptible to a human observer.

Response to sinusoidal movements

If the valve displacement y in an equation such as 24 varies sinusoidally with frequency $\omega/2\pi$, the sinusoidal variation produced in Q can be obtained by writing $j\omega$ instead of D in the transfer function f(D)/F(D) and expressing the resulting complex number in polar form. The modulus of the number will then represent the ratio of the amplitude of Q to that of y, and the argument will represent the phase lag.* If this is done numerically for a selection of values of ω covering the full range from zero to infinity, a complete picture of the frequency response of the system emerges. The results can be plotted to give a curve which is of great value when considering the performance of the pump and discharge system, either by itself, as in this report, or in combination with other parts of the complete control loop.

* *Ibid.*, p. 116 ff

System with constant-speed pump

From the foregoing, and from equation 26, the transfer function to be evaluated is

$$\frac{C_1}{1+j\omega T_1}=C_1\left(\frac{1-j\omega T_1}{1+\omega^2 T_1^2}\right)=\frac{C_1}{\sqrt{(1+\omega^2 T_1^2)}}e^{-j\phi} \quad (32)$$

$$\text{where} \qquad \tan\phi = \omega T_1 \quad (33)$$

The ratio of the amplitude of Q to that of y (i.e. the vector gain) is $C_1/\sqrt{(1+\omega^2 T_1^2)}$ and the phase angle by which the oscillation of Q lags behind that of y is ϕ as defined above.

By plotting the vector gain radially, at an angle ϕ below the real axis, a polar diagram is obtained which for equations similar to 25 is a perfect semicircle. This curve, the transfer locus for the system, is plotted in Fig. 4, omitting the constant C_1. At very low frequencies the vector gain is almost unity and the phase lag negligible, implying that the flow rate follows the regulating valve closely, but at higher frequencies the gain diminishes and the lag increases. At very high frequencies the amplitude of Q almost disappears, and the little variation which remains lags almost 90° behind the regulating valve movement, which is assumed to be of unit amplitude whatever the frequency.

Systems with governed pumps

From equation 29, the transfer function is

$$\frac{C_1(1+j\omega T_3)}{(1+j\omega T_1)(1+j\omega T_2)}=\frac{C_1}{\sqrt{[(1+\omega^2 T_1^2)(1+\omega^2 T_2^2)]}}e^{-j\phi} \quad (34)$$

$$\text{where } \tan\phi = \frac{\omega(T_1+T_2-T_3+\omega^2 T_1 T_2 T_3)}{1+\omega^2(T_1 T_3+T_2 T_3-T_1 T_2)} \quad (35)$$

Transfer loci are plotted in Fig. 4 for the values of T_1, T_2 and T_3 given in Table III, again omitting the constant C_1 for ease of comparison.

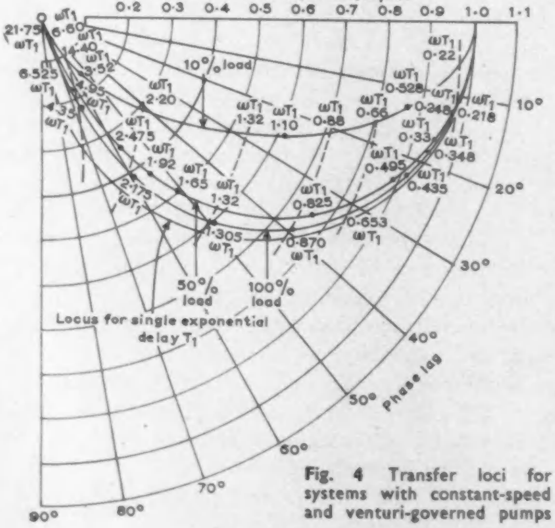


Fig. 4 Transfer loci for systems with constant-speed and venturi-governed pumps

TABLE I *Primary constants for systems with governed pumps*

% FULL LOAD	100	50	10
$\frac{\pi l}{30}$	0·539	0·539	0·539
$\frac{l\rho}{A}$	5500	5500	5500
Λ_D	0·520	0·359	0·260
$*K_F$	$0{\cdot}428 \times 10^6$	$0{\cdot}915 \times 10^6$	$5{\cdot}44 \times 10^6$
$\dagger K_F$	$0{\cdot}162 \times 10^6$	$0{\cdot}262 \times 10^6$	$1{\cdot}72 \times 10^6$
K_G	5600	5810	5860
K_P	715	715	715
K_Q	92,000	46,000	9200
K_R	199	189	186
$*K_S$	$0{\cdot}0613 \times 10^6$	$0{\cdot}1594 \times 10^6$	$0{\cdot}920 \times 10^6$
$\dagger K_S$	$0{\cdot}0613 \times 10^6$	$0{\cdot}0686 \times 10^6$	$0{\cdot}300 \times 10^6$
K_T	1·190	1·003	0·865
K_W	$2{\cdot}90 \times 10^{-6}$	$2{\cdot}90 \times 10^{-6}$	$2{\cdot}90 \times 10^{-6}$
$\dagger K_Y$	0·1932	0·0966	0·0193

*Applicable to pressure governing only.
†Applicable to venturi governing only.

Tables of derived constants for systems with governed pumps

TABLE II *Constants for pressure governing*

LOAD %	T_1 s	T_2 s	T_3 s	C_1 ft²/s
100	0·12	0·02	0·04	5
50	0·06	0·02	0·04	5
10	0·04	0·006	0·04	6

TABLE III *Constants for venturi governing*

LOAD %	T_1 s	T_2 s	T_3 s	C_1 ft²/s
100	0·44	0·02	0·04	6
50	0·17	0·03	0·04	5
10	0·04	0·02	0·04	6

STABILITY OF COMPLETE WATER-LEVEL LOOP

The principal components of a complete boiler-water-level control loop are

1. the feed-regulating-valve control system, which determines the movements made by the valve in response to changes in water level;
2. the pump, turbine, governor, feed discharge system and regulating valve, which together determine the response of feed flow to movements of the regulating valve spindle;
3. the boiler, the internal details of which determine the response of the water level to changes in feed inflow.

These three components or assemblies form a complete loop, the stability of which depends on their combined characteristics. If the regulator is of the three-element type incorporating a flowmeter, items 1 and 2 will be further linked; but this case is not considered here.

Each of the above components makes changes in a certain quantity (regulating valve lift, feed flow or water level) in response to changes in another quantity (water level, regulating valve lift or feed flow respectively), and for each component a response curve on the principle of Fig. 4 could be plotted if enough information were available. In the case of oscillations which affect the whole system, the frequency will be the same for all the components, each of which will be responsible

for a certain phase lag, and there will be one or more frequencies at which the sum of these lags is 180°. If the combined vector gain (i.e. the product of the vector gains of all the individual components in the loop) at the lowest of these frequencies exceeds unity, the system as a whole will almost certainly be unstable in practice, although this is not strictly a sufficient condition for instability.

Oscillations

Common sense and experience tell us that any oscillations affecting the complete water-level control system in practice are likely to have a period of many seconds (see, for example, Fig. 9). Reference to Fig. 4 shows that at such low frequencies the lag in the response of feed flow to regulator movement is negligible with the correctly designed venturi-governed system described later under *System with venturi-governed pumps*. But if the venturi action is excessive in relation to the system resistance (see *Onset of instability* later in this article), the phase lags of Fig. 4 will be drastically increased, and so also will the total lag for the complete loop, which may thereby be rendered unstable even though the pump, turbine, governor and discharge system still form a stable combination when divorced from it (as would be achieved by adopting hand feed).

The obvious remedy in such a case would be to reduce the venturi action, but it might be equally possible to restore stability by modifying the feed-regulator control system. If the proportional band of this component were doubled, the movement of the valve for a given change in water level would be halved. The vector gain for the regulator control system, and hence for the complete loop, would also be halved, and the latter might well be reduced to something less than unity for the frequency for which the total phase lag was 180°. Stability would thus be restored.

Instability of the whole system occurred on the Pametrada full-scale test bed when a large marine installation was first run at high power, as shown in Fig. 9. It was proved by experiment that stability could be restored either by eliminating the venturi action or by widening the proportional band of the regulator, each of these methods being entirely effective by itself. This is completely in accordance with the above argument.

Matching of components

If a man wears one gum-boot and one bedroom slipper his gait will be oscillatory even though there is nothing wrong with either article; it is the combination of the two which is at fault. Similarly, it is frequently impossible to attribute instability in the operation of a feed system to any single component. The fact is that satisfactory operation of an installation of new design cannot be guaranteed unless the complete water-level control loop is considered as a whole at the design stage to ensure that all components are properly matched. Otherwise, extensive and expensive investigation may be needed to diagnose and remedy the resultant troubles, *which may be peculiar to the complete system* and be entirely unsuspected from individual component type tests.

A design study of the type envisaged above need be no more difficult, once it has become an established routine procedure, than other calculations which are performed without question for any new design. The immediate difficulty is the scarcity of information concerning the transient performance of actual complete installations, and until this information becomes available enabling the theoretical work to be checked in a few practical cases, numerical calculations will be worth very little.

Evidently there is an urgent need for careful experimental work to determine at least the following data for several different installations: —

1. Pressure-flow and torque-flow characteristics for feed pump;
2. Torque-speed and torque-lift characteristics for feed pump driving turbine and governor valve;
3. Lift of governor valve as a function of speed, pressure and/or flow, and time lag (if any) in governor valve movement;
4. Pressure-flow characteristics for feed discharge system at each of several different regulator openings;
5. Proportional band, integral action time and lags in feed regulator control system (plus any other relevant information if regulator is of unusual design or is controlled partly by factors other than boiler water level);
6. Response of boiler water level to changes in feed flow under all possible steaming conditions;
7. Effect of feed flow changes on boiler drum pressure under all possible steaming conditions.

Given all the above information, which would have to be obtained partly from component type tests and partly from full-scale trials of the complete plant, it should be possible to construct a comprehensive theory from which the characteristics of the complete water-level control loop could be estimated. Further full-scale trials would then provide practical confirmation (or otherwise) of these calculated characteristics. It is not to be expected that success would be achieved at once, for certain neglected factors would probably prove to be important and the theory would have to be revised, but reasonable correlation should eventually be attainable. It might then be possible to lay down a few comparatively simple rules which, if followed at the design stage of a new job, would be a complete safeguard against instability due to bad matching of components.

It may be thought that this represents a poor reward for a major experimental and theoretical effort, but this view will not be held by many who have first-hand practical experience of the utter chaos which can be caused by the application of ill-matched automatic controls to a complex, highly rated, modern steam plant.

The present theoretical work should be regarded as merely the beginning of a very large job, and it will remain of very limited value until the equations derived in it have been proved or disproved by dependable experimental work.

SPECIMEN CALCULATIONS FOR TYPICAL BOILER FEED PUMPS

System with constant-speed pump

Design data

Pump

Speed	3000 rev/min
Full load flow rate	100,000 lb/h (=0·470 ft³/s)
Full-load discharge pressure (gauge)	650 lb/in²
No-load discharge pressure (gauge)	800 lb/in²

A flatter characteristic would probably be obtained in practice, but this example has been chosen for comparison with other systems, described later, in which the same pump is considered with different governors. The characteristic is here assumed to be parabolic, and horizontal at no load, as shown in Fig. 5. The effect of a flatter characteristic is mentioned briefly below.

Discharge system

Boiler drum pressure (gauge)	550 lb/in²
Bore of discharge pipe	3½ in
Effective length of discharge pipe (including economizer etc.)	200 ft
Density of feed water	59·1 lb/ft³

Estimation of exponential delay

From equations 15 and 25, the exponential delay is

$$T_1 = l\rho/A(K_Q + K_S) \quad (36)$$

From above,

$$l = 200 \text{ ft}$$

$$\rho = \frac{59{\cdot}1}{32{\cdot}2} = 1{\cdot}835 \text{ lb s}^2/\text{ft}^4$$

$$A = 0{\cdot}0668 \text{ ft}^2$$

$$l\rho/A = 5500 \text{ lb s}^2/\text{ft}^5 \quad (37)$$

The total pump discharge pressure p_D at any total flow q is given by $p_D = 144\{800 - 150(q/0{\cdot}47)^2\}$lb/ft² (38)

Hence $$K_Q = \frac{dp_D}{dq} = 144 \times 1358\, q \text{ lb s/ft}^5 \quad (39)$$

Since the boiler drum pressure is 550 lb/in² gauge, the total system resistance p_S at any total flow q' in equilibrium must be

$$p_S = p_D - 144 \times 550 = 144\{250 - 150(q'/0{\cdot}47)^2\} \text{ lb/ft}^2 \quad (40)$$

the equilibrium opening of the feed regulator being such as to make this true. If the flow then changes to some other value q while the regulator setting remains unaltered, the system resistance will become

$$p_S = 144\{250 - 150(q'/0{\cdot}47)^2\}(q/q')^2 \quad (41)$$

Hence

$$K_S = \frac{dp_S}{dq}$$

$$= 144\{250 - 150(q'/0{\cdot}47)^2\}2q/(q')^2 \quad (42)$$

We are concerned only with the very small changes about the equilibrium point, at which $q = q'$. At this point.

$$K_S = 144(500/q - 1358\, q)\text{lb s/ft}^5 \quad (43)$$

which can be combined with 39 to give

$$K_Q + K_S = 72{,}000/q \text{ lb s/ft}^5 \quad (44)$$

Substituting equation 37 and 44 into 36, $T_1 = 0{\cdot}0764q$ s (45)

The worst condition occurs at full load, and even then the exponential delay is only about 1/30 s, which is utterly negligible. Such a system could not possibly be accused of causing instability in the water-level control loop.

For a more suitable pump with a no-load discharge pressure of 700 lb/in² gauge, falling parabolically to 650 lb/in² gauge at full load, equation 45 would be modified to

$$T_1 = 0{\cdot}1274p \text{ s} \quad (46)$$

which is not quite so good as the previous case but would still be entirely satisfactory in practice.

In view of this obviously excellent performance there is no point in evaluating the detailed response to feed regulator movements.

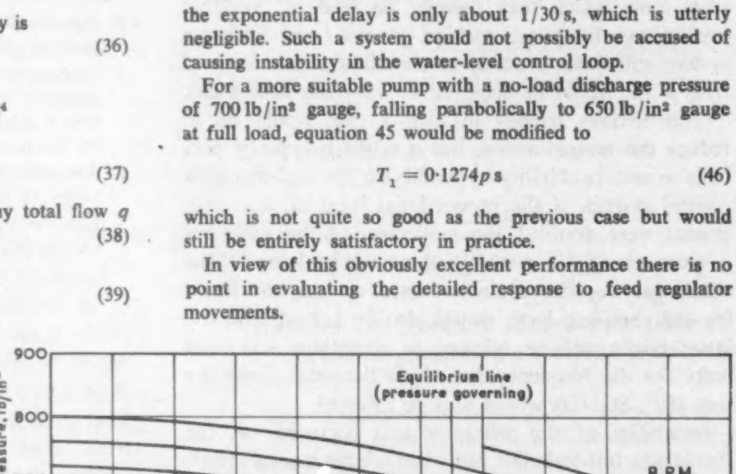
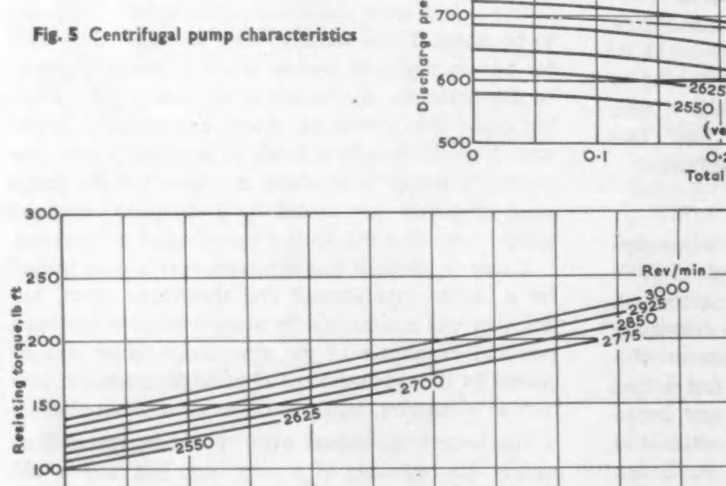


Fig. 5 Centrifugal pump characteristics



To be continued

Fig. 1 Determining the strength of a coal seam with the 'penetrometer'

Work at the N.C.B.'s Mining Research Establishment is leading toward the automatic and remote control of mining machines

Coal winning and control

FAR-REACHING EFFECTS on mining practice are expected to result from work proceeding at the National Coal Board's Mining Research Establishment at Isleworth, Middlesex. The aim is to produce coal inexpensively, efficiently and yet safely, and this entails not only research into ways of solving old difficulties, but also an original approach to such new problems as the automatic and remote control of machines, and methods of supporting strata. Alongside these developments, work proceeds on various forms of instrumentation.

Machine performance

Nowadays about 40% of coal won is mined by machine. The performance of a coal-winning machine in the seam depends upon the strength of the coal, and this strength may differ from that measured in the laboratory owing to the effect of the overlying beds extending from the seam to the surface, which produce extremely high pressures. A simple method of measuring the *in situ* strength is provided by the 'penetrometer' (Fig. 1). This consists of a 0·25in steel rod which is pushed horizontally into the coal-face by a hydraulic ram. The force required to do this gives a graph of load against penetration at that point. The workability of coal can thus be correlated with the performance of plough-type machines.

Ploughing is a means of winning coal in which the plough is hauled back and forth along the face by chains. The method has several advantages, but difficulties have arisen in practice, mainly because the ploughs most widely used have been designed to work with soft German coals. In order to find the important characteristics of machine and coal that determine the ploughability of a seam, M.R.E. have instrumented an operational plough so that the forces acting on it while taking a production cut can be measured. These are the haulage force in the chain and the resultant force acting on the cutting head. The force sensors used are wire-resistance strain-gauges, and these are affixed to appropriate members of the plough structure. Signals from the gauges are taken from a cable to amplifying and recording equipment in the gate road. This equipment is intrinsically safe: in other words, no circuit fault can develop which may produce a spark to ignite an explosive mixture of methane and air.

The efficiency of a coal-winning machine is best evaluated when it is actually cutting coal. In the past, this has not been possible because mechanical measuring devices are rarely sufficiently sensitive, and conventional electronic instruments cannot be used underground unless they are contained in large flameproof enclosures. Consequently, once a machine has been taken underground, information about it is limited. To overcome this difficulty, M.R.E. have designed a range of intrinsically safe measuring devices of transistorized type.

A particular application is on an experimental face at Donisthorpe Colliery where the performance of a range of old and new mining machines is being assessed. It is now possible to measure: haulage force in the rope or chain pulling the machine across the face; the torque or cutting power in the cutting shaft of the machine; the speed of the cutting shaft; the motor supplies (i.e. power, voltage and current); the flow of cooling water through the electric motor; water temperatures; and hydraulic oil temperatures and pressures.

These data are obtained from pick-ups mounted on the machine and recorded on a twelve- or 24-channel recorder (Fig. 2) some distance from the face and coupled to the machine by a multi-core cable.

Sensing seam position

Any system for the remote control of a mining machine must keep the machine within the coal; i.e., the machine must follow undulations in the seam and not cut into either the roof or the floor. Coal-sensing equipment designed by M.R.E. caters for this requirement by measuring the amount of coal left on the floor as a coal-getting machine advances. The basis of this technique lies in the fact that the amount of gamma radiation scattered back to a Geiger counter from a radio-active source immediately on the top of a layer of coal left on the floor of a seam, can be related to

the thickness of that coal layer. The equipment will measure layers of floor coal up to 4 in thick with an accuracy of ± 0·5 in, greater thicknesses being indicated as in excess of 4 in.

The first coal-winning machine to be fitted with this equipment is a 'Midget Miner' (Fig. 3) at New Lount Colliery in the N.C.B.'s East Midlands Division. This machine cuts 2 ft 3 in of coal out of a seam approximately 2 ft 7 in thick. It moves on two skids, in each of which a coal-sensing equipment is mounted as close as possible to the cutting heads of the machine. The main body of the Midget Miner is coupled to the skids by means of the four hydraulic jacks which steer the machine in the vertical plane. The operator is now provided with two meters—one for each coal sensor—and his task of controlling the position of the machine within the seam has been greatly simplified. Excursions into the roof or floor are understood to have been virtually eliminated. This has improved roof and floor conditions, and reduced the amount of 'free dirt' in coal.

The next stage is, of course, to design a servo-system which will link the sensing units with the hydraulically operated steering jacks, and so give fully automatic steering control in the vertical plane. There is some hope that this will have been done by mid-1961.

Strata instruments

The earth pressures in the vicinity of an excavation at a great depth may be considerable. Often it is not

Fig. 2 Underground recording equipment at Donisthorpe Colliery

possible to resist them, and supports that yield gradually—hydraulic supports—so as to prevent a breakdown of roof and walls are in common use. Instruments that will measure loads on yielding supports, and also the stresses and strains in the adjacent strata, are therefore required. Among the many designed at M.R.E. are load cells for measuring loads on props and roof bolts, an 'extensometer' for measuring change of strain on a rock surface, and a borehole plug for measuring change of stress at the end of a borehole. These instruments are based on the use of the wire-resistance strain-gauge, and readings are taken by means of intrinsically safe measuring equipment. Non-electronic instruments include a 'romometer' for measuring relative movement between roof and floor, and a hydraulic load-cell for measuring forces on packs.

'Sonic' gauges for measuring strains in concrete linings to shafts and roadways, have also been developed. These gauges, which are embedded in the concrete, contain a length of fine wire under tension, the tension being varied by the strain to which the gauge is subjected. The frequency of vibration of the wire when it is plucked by means of an electro-magnetic impulse, is measured to determine the strain.

Controlling face supports

Some modern mining machines are capable of much higher rates of extraction than are being achieved, the rate of advance of a face being limited by the time taken to move and reset the props and bars which support the roof at the face. A solution is the remote operation of all the supports from a point in the supply road. Preliminary underground experiments at Measham Colliery in the East Midlands Division have established the feasibility of sequential hydraulic control of powered face supports, and further trials will be carried out in the North Eastern Division. Two systems are to be tried: in one the movement of the supports will be entirely controlled by hydraulic circuits; in the other electrohydraulic techniques will be used.

For a system providing remote operation of powered supports to be satisfactory, the operator in the gate road must have information that the individual supports have been advanced and reset correctly against the roof. An intrinsically safe instrumentation scheme to give this information has been developed for a face containing up to 256 support units, all the signalling and control information being carried over a single 25-core cable.

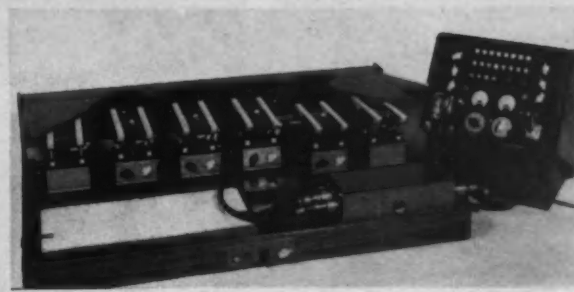
A model showing part of a face fitted with powered supports, together with the associated control unit, is illustrated in Fig. 4. The 'chocks' are attached to the conveyor by double-acting hydraulic rams, and they are advanced by being pulled forward by the rams; when the chocks are in position and supporting the roof, the same rams can be used to advance the conveyor.

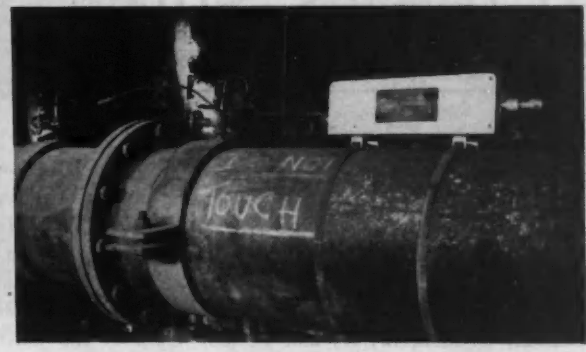
Fig. 3 The 'Midget Miner' coal cutter at New Lount Colliery is fitted with nucleonic coal-sensors on each of its two steerable skids

Fig. 4 (right) Model showing part of a coal face fitted with powered supports, together with the control unit

Fig. 5 (below) This recording flame methanometer operates on Davy lamp principles, but thermocouples sense temperature increases when gas is present

Fig. 6 (below, right) Methane drainage pipe fitted with acoustically operated heads to give the gas concentration





Methane measurement and control

A mine's atmosphere must be sampled for methane gas and, as existing instruments sample instantaneously, or over short periods, and only provide information on conditions at the time of test, M.R.E. have developed instruments which operate continuously. For gas, warning is required whenever the concentration approaches an explosive value, and for this purpose a butane flame methanometer has been developed. This has a small flame burning in a gauze-protected enclosure, as in the Davy lamp. Instead of observing the 'cap' above the flame, thermocouples show the increased temperature when gas is present in the air, their electrical output operating an indicator, recorder or, via a relay, an alarm. Its accuracy depends on the constancy of the flame, and this is achieved by using butane fuel controlled by a precision pressure regulator. The present model (Fig. 5) is accurate to about 0·05% methane.

One direct consequence of the increased rates of face-advance now being achieved, can be a disproportionate increase in the percentage of methane in the ventilation air, and high-concentration methane is now being drained from a number of collieries. Holes are bored in the disturbed ground around the workings and methane drained away for use in colliery boilers or by the Gas Board.

Any fracture of a pipe, or other leakage of air into the methane drainage range, will reduce the methane content of the gas and it can bring the gas mixture below the upper limit of explosibility. It is therefore important that a leak be located and repaired quickly.

M.R.E. have designed and installed at Haig Colliery in the N. and C. Division, a monitoring system in which methane-measuring heads, employing an acoustic technique, are used to monitor the main drainage pipes at points up to five miles from the shaft bottom. Signals indicating the gas concentration are transmitted to the surface and displayed on a chart recorder in the control room. The system is based upon measuring the sound velocity between transducers within the methane-carrying pipes. Alarms are operated if preset limits are exceeded to draw attention to the fact that a potentially dangerous situation may be arising.

An extension of the principle is the automatic control of the concentration of methane that is being drained from behind a sealed-off waste area at Avon Colliery, South Wales. There the gas is being sold to the local Gas Board and automatic control is necessary because the concentration rises and falls inversely in accordance with the movement of the barometer.

Intrinsic safety

Electrical equipment for use underground must be safe in that it cannot ignite any fire damp (methane) present in the workings. This can be achieved by either placing the equipment in flameproof boxes or by making it 'intrinsically' safe. Light-current equipment can be made intrinsically safe, although at present the assessment of safety is entirely empirical. Hence, a basic investigation into the ignition of methane/air mixtures by sparks initiated in various ways is being made. Standards of safety have risen with the result that electrical units which satisfied safety requirements when they were first installed, now fail to do so. Replacement of the old equipment involves a heavy capital outlay, and consideration is being given to the possibility of modifying the old equipment, at a substantially lower cost, to bring it to the required standard.

Current attention is being given to 'gate end' control circuits which control, through an intrinsically safe circuit, the switching 'on' and 'off' of mining machines, conveyors, etc., and different types of equipment require different solutions. New means of achieving safety are being examined, including the gas discharge tube type of spark arrester, and the Zener diode.

Physics show 1961

THE ONLY MAJOR CHANGE at this year's 'Phys. Soc.' show is that instead of being the Forty-fifth Physical Society Exhibition of Scientific Instruments and Apparatus, it has become The Annual Exhibition of The Institute of Physics and The Physical Society. Apart from this change of title, things—and indeed many of the exhibits—are much as ever. As usual the show will be held at the Royal Horticultural Society's Old and New Halls, Westminster, London, S.W.1, that is, just south of the junction of Victoria Street and Artillery Row. The dates are Monday 16–Friday 20 January.

The Phys. Soc. show has many critics, but there is little doubt that it still is one of the most important exhibitions of the control and instrumentation man's year. Tickets are available from The Institute of Physics and The Physical Society, 47 Belgrave Square, London S.W.1. Attendance is strongly recommended.

ANALYTICAL EQUIPMENT

Many of the exhibits will be concerned with analysis in the broadest sense.

A **recording flame photometer** to be shown by Evans Electroselenium (12) is designed primarily for the continuous measurement of sodium concentrations. A sensitivity of 1 part in 10^8 sodium for f.s.d. may be obtained.

On view at the Unicam stand (107) will be the SP.200 **infra-red spectrophotometer** designed for routine analysis. Spectra are presented on foolscap charts which have linear wave-number and transmittance scales.

A **spectro-photometer,** to be shown on the Perkin-Elmer stand (49), records spectra on a linear-absorbance/linear-wavelength basis over the range 190–750 mμm. Their Fractometer **chromatograph,** for which four different detectors are available, will also be exhibited.

In addition to their **argon chromatograph** range of instruments, Pye (100) will exhibit a sensitive **process analyser,** able to detect trace components at concentrations of less than 1 part in 10^6. Various equipments for pH measurement will also be on view. These include an **industrial pH amplifier** which may be used with robust high-resistance glass electrodes. Sensitivity is 100 μA/pH. The standard model covers 2–12 pH. Their **autotitrator-controller** may be used for routine titrations in conjunction with a pH meter, as a controller (using the two channels independently so that one adds acid and the other alkali), or for holding batches of solution at a particular value of pH.

Elliott (125) will show their **process chromatograph** designed for plant analysis of mixtures of most substances which are in the vapour phase below 65°C. The detector is said to give a full-scale reading for less than ½% of any given component under almost all conditions. When used with a peak reader, this instrument will give a continuous output for automatic control.

Guy's Hospital Medical School Physics Department (142) will be demonstrating a **radio-frequency electron-spin resonance spectroscope.** It works at a wavelength of 1 m, and uses a quarter-wave resonant line situated in a 100-gauss field; it is intended for the investigation of free radicals produced by irradiation.

The Water Pollution Research Laboratory will show a **sludge detector** and a **suspended-solids recorder** on the D.S.I.R. stand (47). The former is a portable submersible optical density meter suitable for sludge detection and the approximate measurement of suspended solids concentration. The recorder measures suspended solids in two ranges, 0–100 and 0–1000 parts in 10^6. On the same stand, the British Welding Research Association will demonstrate the **carrier-gas method of hydrogen determination.** Argon is passed over a sample of steel which is heated in a furnace, and the hydrogen evolved is swept along in the argon stream to a hydrogen-sensitive conductivity cell whose output is plotted on a chart recorder.

Mervyn Instruments (119) will be exhibiting the Mervyn-Harwell Mark 3 **square-wave polarograph,** and the plant-stream **gas analyser** Mark 2. This instrument measures and records the amount of one gas in a stream of mixed gases.

On view on the Gallenkamp stand (128) will be an **automatic standard distillation apparatus.** Originally developed by Shell, this equipment has been expanded and includes a refrigerator unit which cools the condenser tank for distillation of materials having highly volatile fractions. Also to be seen will be a **Lloyd apparatus** which uses chemical methods for the determination of oxygen and carbon in gases.

Marconi Instruments (98) will show a **laboratory pH meter** which provides direct readings from 0–14 pH. Any section of the scale may be expanded over a centre-zero incremental range of ±1·4 pH. Full automatic solution-temperature compensation is provided on both ranges.

A **non-dispersive infra-red gas analyser** will be on view on the U.K.A.E.A. stand (39) also a scanning **Fabry-Perat spectrometer.** The latter is intended for measuring the relative intensities of the isotopic components of the hyper-fine spectral lines. Of interest to process engineers will be an automatic **gas-chromatographic analyser** for volatile inorganic fluorides. Free acidity of solutions of uranyl nitrate in nitric acid is a critical parameter in the chemical processng of spent fuel elements from radioactive plant. The U.K.A.E.A., Capenhurst, will show an **acidity meter.** In this instrument, the acidity of the solution is derived from combined measurements of its density and electrical conductivity. A continuous signal, suitable for automatic control, is obtained.

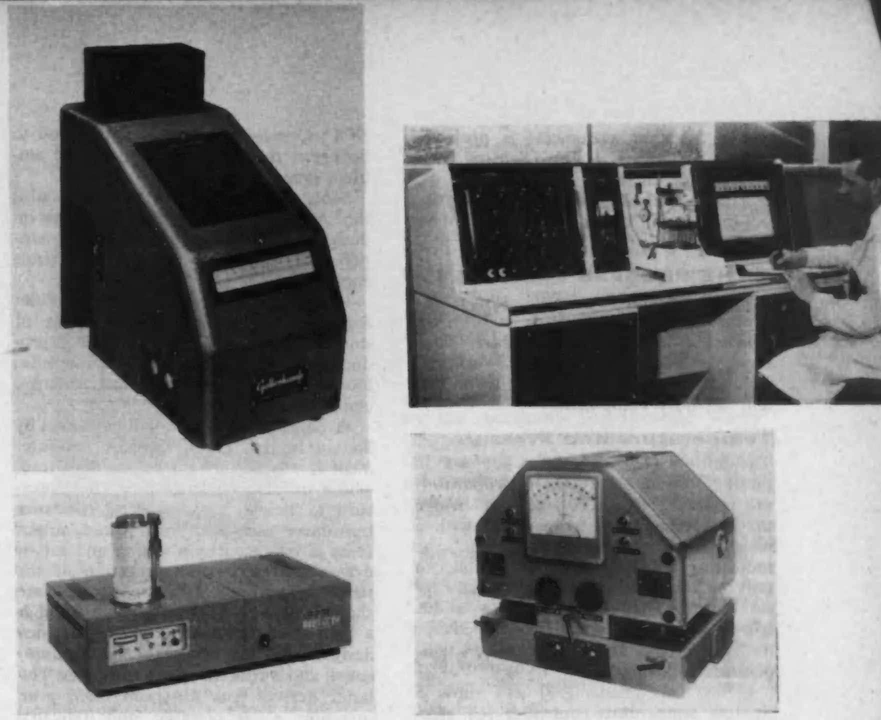
Their Analmatic **auto-titrator** is to be exhibited by Baird and Tatlock (136). This takes samples automatically, performs any necessary functions such as dilution or the addition of reagents before titration, titrates to the end-point, records the results, and can give output signals suitable for automatic control. Amongst other items on this stand are a multi-detector **gas-chromatograph,** designed primarily for fuel analysis, and an automatic **curve-plotting titrator.**

On view at the Admiralty Research Establishment's stand (135) will be a portable **dissolved oxygen meter,** designed to determine dissolved-oxygen concentration in a 250-ml sample of boiler feed water. It will detect from 0·2 ± 0·01 down to 0·001 ± 0·001 parts in 10^6.

Baldwin Industrial Controls (127) will be exhibiting the **Colormat,** an instrument for measuring and comparing the colour of surfaces or powders when illuminated by visible or ultra-violet light.

On the Techne (Cambridge) stand (52), a **recording viscometer** will be shown which measures and prints the viscosity of any liquid from 0·5 cP upwards.

Ekco Electronics (30) are to show their N680 **moisture gauge,** designed for use in paper making. It gives an accurate



Top right is a square-wave polarograph (Mervyn); top left shows a flame photometer (Gallenkamp). Bottom right is an instrument which measures and compares colours (Baldwin); bottom left is a spectrophotometer (Perkin-Elmer)

indication of the moisture content of paper within the range 2-75%.

Among the exhibits which will be on view on the Cambridge Instrument stand (54) is a **multi-point boiler feed-water analyser.** It records continuously the results of up to twelve different analyses, the present model measuring the concentration of dissolved oxygen and hydrogen, conductivity, and pH. Also to be seen will be a **carbon monoxide detector,** having a sensitivity of 400 parts in 10^8 for f.s.d., a **paramagnetic oxygen detector,** and a portable **pH meter.**

Solus-Schall (126) will be showing an **e.h.t. supply** for use with crystallography equipment, and an **X-ray diffractometer** for determining the position, intensity and width of diffraction lines from polycrystals or from single crystals in the plane of motion of the counter tube.

Hilger & Watts (133) are to exhibit the Ultrascan H999, a double-beam recording **spectrophotometer** useful in routine analysis in the range 200–750 mμm. Resolution is 0·1 mμm at 250 mμm, and 0·2 mμm at 50 mμm. Among many other instruments to be shown are a **fluorimeter,** an **electron-spin resonance spectrometer** (developed in conjunction with Microwave Instruments Ltd), and the J40 **Colourmeter.** The latter measures surface colours in terms of the C.I.E. system.

On the A.E.I. stand (131) will be exhibited the LD-2 **mass spectrometer leak-detector,** the MS10 production model **mass-spectrometer,** and an **X-ray micro-analyser** with scanning attachment and range extension.

The Post Office Research Station (137) are to demonstrate an instrument for the **measurement of gas evaluation and in-leakage** of experimental transistors; leak-rates of 10^{-11} lμm/s can be detected.

Griffin and George (123) are to show a wide range of analytical devices including a **gas-density ratio monitor** and an **absorption chromatograph.**

A Wayne Kerr (102) **portable salinity bridge** for measuring the salt content of water will be exhibited. This has been developed in conjunction with The National Institute of Oceanography.

DATA HANDLING

Equipment for processing and handling data will be much in evidence.

Data handling equipment by A.W.R.E. (39) has been developed to speed the assessment of film records, and to present the data obtained in a form suitable for feeding direct to a computer.

A data-handling system said to be capable of **scanning and logging** an unlimited number of process variables, and having an operational accuracy of 0·1% is to be shown by Kelvin Hughes (104).

Digital computer components by Solartron (111) consist of logical element packages intended for the construction of computers and other devices with a 1-Mc/s clock frequency. Their **binary-decimal to decimal translator** is designed to work with their LP 942 analogue-digital converter, whose output it converts to a five-window digital display.

Ericsson (115) are to show a **digital-data link equipment,** which can transmit binary data at speeds up to 500 bauds over media such as the normal Post Office system. Both receiver and transmitter are designed for use with five-hole punched-tape.

Royston Instruments (34) will show examples of the Midas **magnetic-tape data-recording system,** and the CMM **playback and processing equipment.** The latter is an automatic playback and data-reduction equipment for the analysis and processing of flight data. Also to be shown is a **tape transcriber** designed to permit direct interchange of tape between the British standard Midas system, and the American standard system.

G. V. Planer (17) are to exhibit **magnetic-film memory stores.** These consist of thin magnetic-alloy films on a glass base, and allow switching-time measurement as low as 2 mμs. A **millimicrosecond pulse generator** for measuring the switching time of such stores, covers 2–200 mμs, the output being suitable to drive switching elements requiring currents up to 13 A.

G.E.C. Research Laboratories (132) have developed **magnetic films,** for storing information, which have a preferred axis of magnetization in the plane of the film. Pulses of current set the magnetization of each film element in the appropriate direction along the preferred axis, in order to represent the required information in binary-digit form. Stored information is read by disturbing the magnetization and observing the resulting output pulse.

Exhibits by I.C.T. (2) will be concerned with **magnetic thin films.** These include films made from Permalloy-type materials which have an uni-axial anisotropy and which reverse their magnetization by the coherent rotation process. They will demonstrate the use of the Kerry magneto-optic effect to show domain patterns in thin magnetic films.

Lintronic (32) will have a **memory store** for digital data-recording systems, and a fully-transistorized **pulse-pattern generator.**

Elliott (125) will exhibit two computers: the 803, a transistorized **digital computer** with a 4096-word ferrite core store, and a **mechanical analogue computer** designed for use where input information is available in mechanical analogue form. Their multi-channel tape recorder has five tape-speeds, and at 30 m/s will handle frequencies up to 75 kc/s. Also on this stand will be the Panellit Optimat, an **optimizing controller** which operates on the set points of three-term controllers to achieve optimum plant performance.

The National Physical Laboratory (47) are to demonstrate an **analogue model of an adaptive control system.** A criterion of quality of control is chosen, and experimental fluctuations are applied to the controller settings. These fluctuations are cross-correlated with a measure of control quality, and the output of the correlator is used to change the control settings so that control quality improves.

The Admiralty Surface Weapons Establishment (135) will demonstrate a method of **high-speed electronic writing** on a cathode ray tube. Semiconductor switches and ferrite stores produce the required wave-forms.

A **digital indicator** by Sangamo Weston (114) has a moving-coil movement carrying a scale past an optical

system, so that a numeral is projected on to a frosted screen. Sensitivity is 500 μA for full-scale deflexion.

Trace analysis and **graph plotting** equipment will be on view on the Dobbie McInnes stand (105).

THE PROCESS VARIABLES

Those parameters with which the process control engineer is most often concerned—temperature, pressure, flow, level, displacement and speed—will be catered for by a variety of instruments and ancillary equipment.

Temperature and Pressure

The Elliott (125) **Autolarm** for use in mining where fail-to-safe conditions are essential, uses a Wheatstone bridge to detect change in temperature with a resistance thermometer. On 'alarm', the indicating pointer is latched in, and can only be cancelled by the appropriate re-set button. They will also show a **d.c. trip-amplifier** for use with low-impedance millivolt inputs, and a standard-cell **temperature-controller.**

C.N.S. Instruments (59) will show a stepless **temperature-controller** for electric furnaces. This uses a platinum resistance thermometer to change the saturating current in a saturable reactor, so controlling the furnace current.

An automatic apparatus to be demonstrated on the D.S.I.R. stand (47) by the British Glass Industry Research Association measures the **thermal expansion of glasses** up to annealing point, the expansion curve appearing on a continuous chart. The curve may be expanded in both ordinates, i.e. expansion and time or temperature.

Two instruments to be demonstrated by Techne (Cambridge) on stand 52 are the **Sentichart** and the **Universal Tempunit.** The former is designed to detect and record changes of temperature of as little as 0·01°C in the range 30–180°C on a circular chart. The Tempunit is a thermostatic temperature controller with booster heating in addition to the normal heating system. Control is maintained to within ±0·05°C.

The G.E.C. Research Laboratories (132) will be demonstrating a range of **thermo-electric cooling** assemblies. These have cooling powers ranging up to 10 W when operated with a 40°C temperature difference across the junctions.

High temperature thermocouples are to be shown by Morgan Crucible (36). These elements are being developed for peak temperatures in the range 1600 to 2000°C or higher. They will also show a breadboard model of an **electronic analogue** for complicated furnace design.

Cambridge Instrument (54) will exhibit a **hot-roll thermocouple,** designed to measure the temperature of moving surfaces such as the hot-rolls used in textile and paper manufacture. The heat-sensitive element is a thermocouple mounted in a shallow pocket on a flexible strip which presses on the surface of the roll. They will also show the prototype of a portable four-element **temperature-controlled oven** designed to maintain the temperature of four Weston standard cells at a chosen value between 20 and 35°C. Control accuracy is understood to be better than 0·02 °C over a wide ambient range.

Sangamo Weston (114) are to exhibit the **Autotemp,** a thermocouple system designed to measure and limit flame temperature of by-pass turbo-jet aircraft engines.

Pye (100) have a low-level **amplifier** for the measurement and recording of small voltage signals such as those produced by thermocouples or thermopiles. Extremely stable gain and low drift are claimed for this amplifier.

A precision **altimeter** will be shown by Kelvin Hughes (124). Pressure measurement is effected by a force-balance unit, whose output is transformed from pressure to height by a cam. A **pressure transducer** uses a capsule whose output force is balanced by a spring and servo-driven lead screw. The rotation of the screw is a direct function of pressure change. Also to be seen on this stand is a **pitot-static test unit** (a portable device designed for the testing of air data systems), and a true **air-speed computer.** The latter derives true air-speed from pitot pressures, static pressure, and indicated air-stream temperature.

Cambridge Instrument's (54) **presssure transducer** gives an electrical output, and provides ranges from 0–20 mmHg to 0–300 mmHg, gauge or differential pressure.

Flow and Level

A **magnetic flow-measuring** instrument for non-conducting fluids, slurries and dusts, from the Atomic Energy Establishment, Winfrith (39), has a pair of plates forming a capacitor through which the material flows. An alternating magnetic field is used to generate an e.m.f. which measures the flow of the material.

The Admiralty Oil Laboratory's (135) miniature **fluid-velocity** indicator will determine the velocity profile of any fluid, including those which exhibit thixotropic properties. The fluid is pumped through a wide-diameter pipe, and the relative velocity of flow at any point on a diameter of the pipe is measured by a miniature free-running propeller.

Top right is a magnetic-film memory-store (G. V. Planer); bottom right shows eight Autolarms (Elliott) on a fan-instrumentation protection panel for mining installations; below is a process analyser (Pye) capable of detecting trace-components at concentrations of less than 1 part in 10⁶.

A differential-pressure pulsating **flowmeter** by Lintronic (32) utilizes a solenoid to generate the balancing force that is proportional to the square of the feedback current.

Black Automatic Controls (125) are to show a self-actuating **valve,** which maintains a constant flow despite variations in supply or delivery pressure.

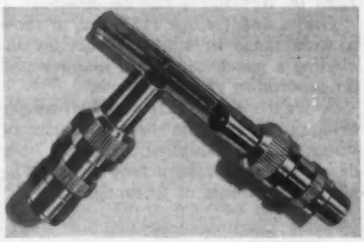
A propeller **flowmeter** by N.E.L. (47) has the propeller mounted in a hydrostatic bearing to reduce friction. An electro-magnetic pick-up is built into the bearing to record the angular velocity of the propeller. On the same stand, Warren Spring Laboratory will demonstrate a **radio-active rotameter.** This is intended for recording low rates of fluid flow at high pressure, or for opaque liquids where conventional methods of detecting the position of a rotameter float cannot be used.

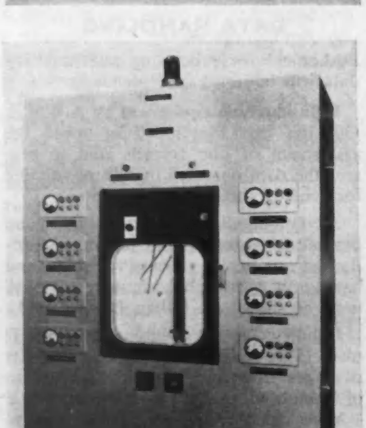
A continuous-response **mercury-switch** will be shown by G. V. Planer (17). This device, using film-resistor patterns, provides an output varying with the angle of tilt.

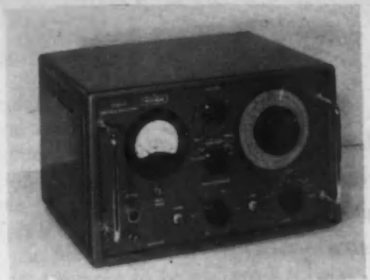
Taylor, Taylor & Hobson (122) are to exhibit the Talyvel **inclinometer,** in which the usual 'bubble' is replaced by a pendulum in conjunction with transducers to provide an electrical displacement single.

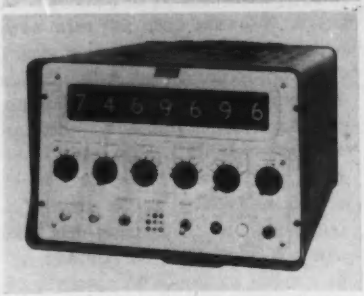
Displacement and Speed

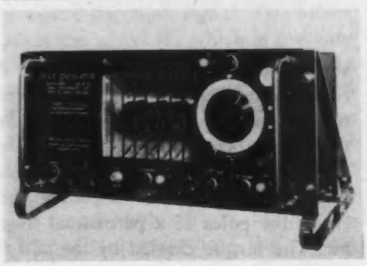
Kelvin Hughes' (104) **precision tachometer,** said to be accurate to 0·1% or better, can use any toothed wheel in an engine to produce an alternating voltage in an electro-magnetic pick-off. This voltage is fed to a presentation unit, where voltage proportional to input frequency is obtained.

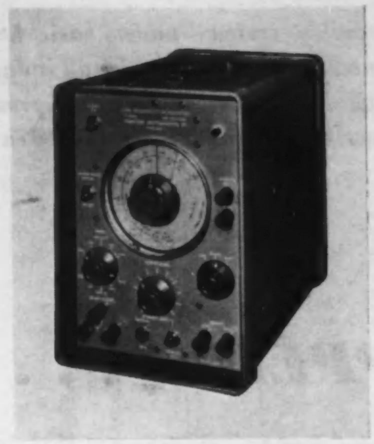












Top left is an analyser-oscillator with a frequency range from 10 c/s to 19 kc/s (Muirhead); centre left is a digital frequency meter (Racal); bottom left is a v.l.f. oscillator (Dawe) with a range from 0.1 to 10,000 c/s; above is an l.f. generator (Marconi) with a range from 0·0033 c/s to 1 kc/s

Ericsson (115) are to exhibit a magnetic **shaft-speed transducer** which is used to indicate speed of rotating shafts without mechanical contact with them.

Racal's (16) **digital frequency meter** has a seven-digit in-line projection display. It measures frequencies (sine wave or pulse) in the range 0–10 Mc/s, and time intervals between two successive positive- or negative-going pulses in the range 0·1 s to 10,000 s.

The National Engineering Laboratory (47) are to show a bi-directional **random input counter,** which will accept a trains of both 'add' and 'subtract' pulses at frequencies up to about 30 kc/s. An interesting feature is that it will handle pulses of opposite sense which coincide or have any degree of overlap.

An electronic **counter** to be demonstrated by Marconi Instruments (98) has an eight-decade digital display. It operates at up to 10^7counts/s, and measures frequency from 10 c/s to 10 Mc/s.

Baldwin Industrial Controls (127) are to show a **differential gauge** (which incorporates a memory device) for the measurement of weight of coating in continuous-coating processes.

The British Electrical and Allied Industries Research Association (47) will exhibit an omni-directional **gust anemometer,** designed to measure the horizontal component of wind velocity regardless of its direction. On the same stand, the National Physical Laboratory will have a **photo-electric microscope,** developed primarily to improve the precision of fiducial settings in the comparison of line standards. A single setting has an accuracy better than 2 μin at 98% confidence level, and the instrument has a linear measuring range between 0·0002 and 0·0004 in.

An **extrusion-speed transmitter** by Cambridge Instrument (54) continuously measures the ram-speed of hydraulic extrusion presses using a force-balance servo-system. The current needed to maintain balance is 0–7·5 mA, and this is independent of line resistance up to 2000 Ω.

A new method of **measuring strip-speed** in rolling mills will be shown by B.I.S.R.A. (53). Two photocells are set on two illuminated spots on the strip surface, the spots being a known fixed distance apart; surface irregularities form a pattern in the output of the first cell, which will be repeated by the second cell after an interval depending upon strip-speed and the distance between the photocells. If the signal from the first photocell is delayed and then added to the second photocell's signal, the combined output will be at a maximum when the delay time introduced is equal to the time taken for a point on the surface to travel between the photocells. Strip-speed is calculated from the delay time and the distance between the photocells.

Muirhead (28) will be exhibiting a **wave-analyser** which automatically analyses and graphically records noise and vibration signals. The equipment performs amplitude/frequency analysis of steady signals, and amplitude/frequency time-analyses of non-steady signals over the range 10 c/s to 19 kc/s.

Pye (100) are to show two **a.c. bridge amplifiers** manufactured to R.A.E. designs; one is for use with push-pull inductance accelerometers, the other is for use with resistance strain-gauges and contains very stable bridge resistors with matched temperature coefficients. Also on show will be differential-induction **linear-displacement tranducers.** Linearity is of the order of ±2% of the largest specified displacement, which is from 1 to 8 in, according to type.

Based on a N.E.L. design, a read-out **extensometer** by C.N.S. Instruments (59) consists of a metal-cored differential transformer connected so as to form two arms of a mutual inductance bridge. Intended for creep-testing, the bridge balancing dials may be calibrated in percentage strain or micro-inches.

A frigate model for the investigation of **ship motion in waves** is to be shown by the Admiralty Experimental Works (135). An aircraft horizon gyro is used for measuring roll and pitch, and an acceleromotor to sense vertical motion; yaw is measured by a separate gyro.

SERVOS AND ANCILLARIES

Among the many exhibits by Dawe Instruments (118) will be a **very-low-frequency oscillator** with a frequency range from 0·1 to 10,000 c/s. Normal and quadrature outputs are provided, each continuously variable up to 25 V maximum into 10 kΩ.

The Admiralty Materials Laboratory (135) have developed a servo-amplifier constructed from transistorized modules and standardized sub-units. The demonstration is to be of a split-field motor-driven servo-system. H.M. Underwater Detection Establishment have a **precision oscillator** with a frequency range from 50 c/s–3·5 Mc/s. Its output is 12 V maximum into 600 Ω.

A **low-frequency generator** to be shown by Marconi Instruments (98) delivers sine, square, or 'ramp' waves over the frequency range 0·0033 cs/ to 1 kc/s.

Sangamo Weston (114) will show a **servo-potentiometer** that gives 20 mA output for a 1-mV input signal. Output is proportional to input, and the load may be up to 1000 Ω.

Two instruments to be shown by Airmec (46) are a **very-low-frequency signal generator,** and a **phase meter.**

MACHINING AND MEASUREMENT

A new technique for producing **master radial scales** to an accuracy of ±1·5" of arc has been developed by the National Engineering Laboratory (47). The use of radial scales in a Moire-fringe error-correcting system will be demonstrated on a circular dividing table.

A **grinding bridge** by Wayne Kerr (102) provides continuous indication of dimensions during grinding, and has facilities for automatic control.

A.E.I. (131) are to show the **pneumatic gauging** of the internal bores of tubes, and also the measurement of internal dimensions of other components.

An **ultrasonic flaw-detector** by Ultrasonoscope (82) has an operational frequency range of 0·5 to 10 Mc/s, and a maximum depth range (in steel) of 20 ft.

Taylor, Taylor and Hobson (122) are to exhibit a prototype equipment that enables the **surface finish** of a 1-mm diameter ball to be measured and recorded in half-millionths of an inch.

A monthly review—under basic headings—of the latest control engineering developments for all industries; specially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are not specialized in instrument and control systems

IDEAS APPLIED . . .

. . . to RECORDERS

Null-balance potentiometric instrument without slide-wire

Conventional instruments for recording small potentials (such as those generated by thermocouples) measure these potentials by comparison with the potential across part of a resistance wire connected to a constant-voltage source; this comparison potential is varied by means of a contact sliding on the wire. In systems of this kind, faulty contact can cause unsatisfactory performance, particularly in unfavourable environments.

In a new range of Kelvin Hughes recorders, the slide-wire has been replaced by an electromechanical force-balance system. Fig. 1.1 illustrates the main difference in principle between the two systems. In the conventional null-balance arrangement, a constant voltage source *E* is connected across the slide-wire *AB*. The potential between *A* and *C* is compared with that of the thermocouple (or other source) *X*. Any difference between the two potentials is sensed by the detecting device *D*, which produces an output signal proportional to the difference. After amplification, this signal is used to drive the reversing servo-motor *M*, which moves the sliding contact *C* in the appropriate direction to achieve balance, and simultaneously positions the recording mechanism.

In the new recorder, the potential of the source *X* is balanced against that across the fixed resistance *R*. This is achieved by varying the current through *R*. As in the conventional system, any difference in the opposing potentials is detected, amplified, and used to drive a servo-motor which positions the recording mechanism. Instead of moving a sliding contact,

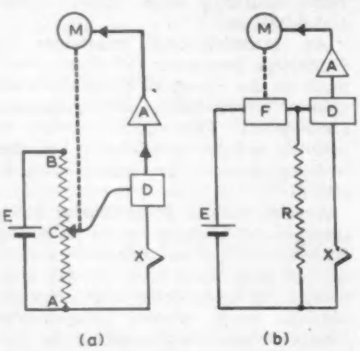


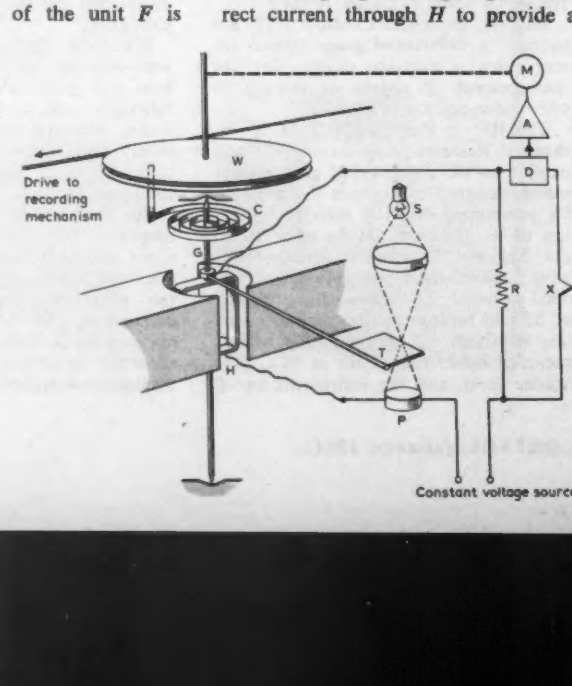
Fig. 1.1 Simplified circuits of: (a) conventional self-balancing potentiometer; (b) system using electromagnetic force-balance converter instead of slide-wire

however, the servo-motor controls the tension in a spring in the force-to-current transducer *F*, thus achieving balance by changing the current through *R*.

The mechanism of the unit *F* is shown schematically in Fig. 1.2. A force balance is achieved between the torque applied to the spindle *G* by the coil spring *C*, and that applied by the electro-magnetic forces acting on the coil *H*, which is suspended between the poles of a permanent magnet. The torque exerted by the coil *H* is proportional to the current through it; that exerted by the spring is linearly proportional to the rotation of the wheel *W* (which is attached to one end of the spring) relative to the spindle *G*.

Also attached to the spindle *G* is the vane *T*, which forms part of a photo-electric position-detecting system. Light from a source *S* is focussed in the plane of *T*, and falls on the cadmium sulphide photo-cell *P*; this acts as a variable resistance in series with *R*, *H*, and a constant direct-voltage source. Because of this focussing arrangement, very small movements of *T* produce large current changes in this circuit. For any given torque applied to *G* by spring *C*, *T* will take up a position giving the correct current through *H* to provide a

Fig. 1.2 Schematic diagram of the force-balance system



balancing torque. The sensitivity of the arrangement is such that the required range of balancing torques is provided with negligible movement of the vane *T*, so that a virtually linear force-to-current conversion is effected.

As previously described, the potential difference to be measured is compared with the drop across *R*, and a difference signal is generated which is used to adjust the tension of the spring and to move the recording mechanism. The comparitor device used is in fact a conventional chopper, producing an a.c. output from a d.c. input, and giving phase reversal to correspond with reversal of the input signal. The direction of rotation of the two-phase motor *M* therefore follows reversals of the input signal. This motor drives the wheel *W*, which is mechanically coupled to one end of the spring *C*, and to the indicating pointer and recorder pen.

An advantage of this arrangement is that it is unaffected by normal variations in the characteristics of the light-source and photo-cell, or by changes in the circuit resistance. The current in the coil circuit is linearly proportional to the measured potential, and can therefore be used to operate other indicators, or as a measured value signal in an electrical control system. Accuracy of measurement is claimed to be ±0·25% of full-scale deflexion for ranges of 10 mV and above, or 0·5% for lower ranges.

to POTENTIOMETERS

Elimination of loading errors

K. C. GARNER, B.Sc.(Eng.), A.M.I.E.E., A.F.R.Ae.S., *College of Aeronautics, Cranfield.*

The compromise between having a relatively high input resistance to economize in driving source power requirements, and a low-valued potentiometer resistance to minimize the effects of loading error, is a well-known difficulty in analogue computer and servo potentiometer design. Two methods have been developed which provide linear operation with an output load connected, both using tapped potentiometers.

The first method gives an accurate linear relation between voltage attenuation and the potentiometer angular setting. This method is particularly suitable for helical potentiometers with geared dials.

The circuit used is as in Fig. 2.1, the equal sections nR of the linear potentiometer being shunted by the resistances $R_1, R_2, \ldots R_m$. These resistances can be chosen so that the voltage ratio, V_o/V_i, follows the required linear law at all the tapping points, with only very slight deviations at other points (Fig. 2.2). The extent of the deviation depends mainly on the number of segments into which the potentiometer winding is divided.

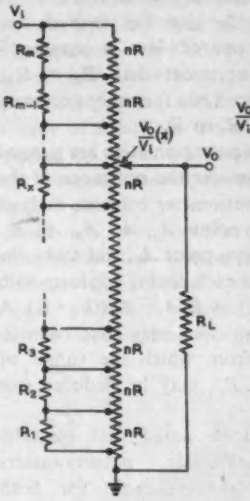


Fig. 2.1 (Left) Circuit for first method of compensation

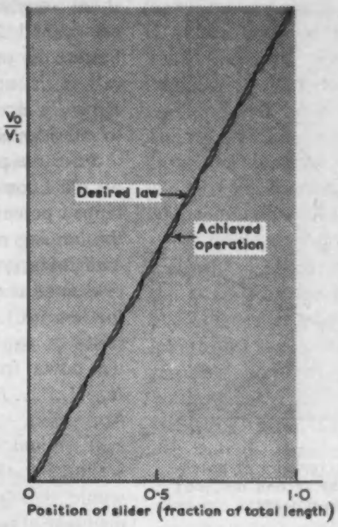


Fig. 2.2 (Right) Typical output characteristic of potentiometer using the first method of compensation

The method of calculating the values of the shunt resistors is given fully elsewhere (*1*), and will not be described here. Each shunt resistor is defined in terms of the resistance of the potentiometer winding *R*, the rerequired voltage ratio V_o/V_i at the tapping points of the resistor concerned, and the resistances of the input and output circuits.

The second method provides linear operation regardless of the value of the output resistance R_L. A tapped potentiometer, with its wiper ganged to a linear potentiometer, is connected in series with the output, as shown in Fig. 2.3. If the wiper is in a position dividing the linear winding in the ratio ratio $K:1$, and the effective resistance of the tapped potentiometer is $f(K)$, it may be shown by normal d.c. circuit algebra that the transfer equation is in general

$$\frac{V_o}{V_i} = \frac{KR_L}{R_L + KR(1-K) + f(K)} \qquad (1)$$

where *R* is the total resistance of the linear potentiometer.

Thus in order to generate the desired law $V_o/V_i = K$, $f(K)$ must equal $-KR(1-K)$. This is clearly impossible with passive components. However, this expression for $f(K)$ has a maximum negative value of $-R/4$ at $K = 1/2$. Thus if we arbitrarily chose that

$$f(K) = R/4 - KR(1-K) \qquad (2)$$

the circuit becomes realizable with passive components.

Any value of the positive resistance greater than $R/4$ is admissable, but inefficient. The overall performance of the ganged pair of potentiometers is now given by

$$\frac{V_o}{V_i} = K \frac{R_L}{R_L + R/4} \qquad (3)$$

where $R_L/(R_L + R/4)$ is a constant for *any* fixed load. Therefore the desired linear law is modified only by a constant scaling factor, the re-

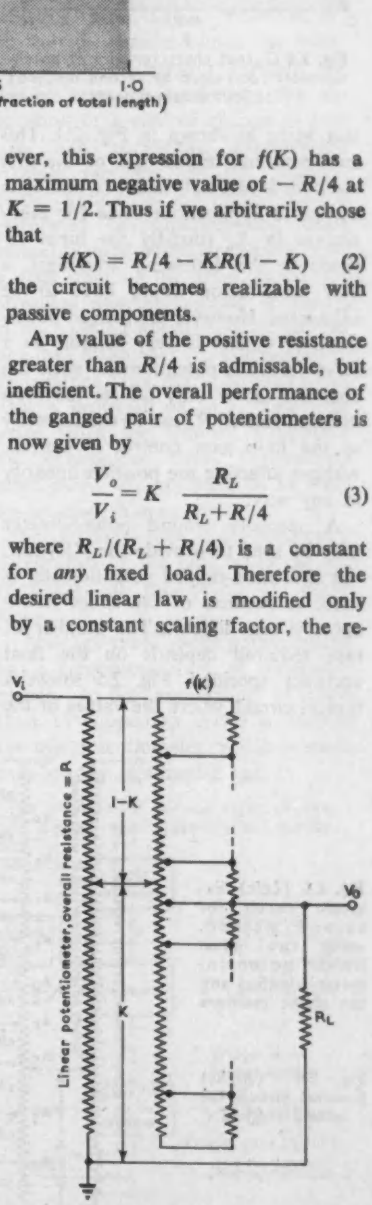


Fig. 2.3 Second method: general form of compensating circuit

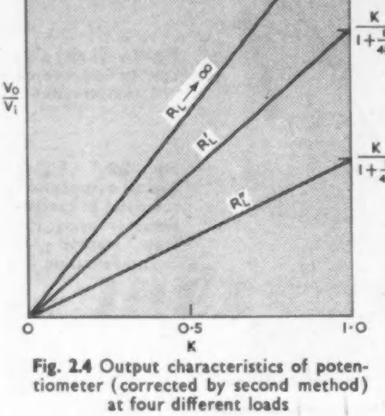


Fig. 2.4 Output characteristics of potentiometer (corrected by second method) at four different loads

sult being as shown in Fig. 2.4. This configuration, unlike that of the first method, is not well suited to analogue computer applications since for every change in R_L (usually the input resistor to the following amplifier), a new scale-factor would have to be calculated. However the ganged potentiometer system is very suitable as a servo feedback potentiometer since the constant factor only affects the loop stiffness. Indeed R_L can be used directly as the loop gain control if desired, without affecting the position linearity in any way.

A specially wound potentiometer may be used to provide the $f(K)$ law, but if a multi-tapped potentiometer is used, calculation of the shunt resistances is not difficult. The number of taps required depends on the final accuracy specified. Fig. 2.5 shows a typical circuit, where the values of the shunt resistors R_1 to R_{10} are to be determined to give the desired law. Since the desired law is symmetrical, it is apparent that $R_1 = R_{10}$, $R_2 = R_9$, etc. Thus it is only necessary to consider R_1 to R_5.

Since the potentiometers are ganged we must consider the resistance of the tapped potentiometer between each of the tapping points A_1, A_2, A_3, A_4, A_5, and the centre point A_0, and make the resistance at each setting conform with the law $f(K) = R/4 - KR(1-K)$. A series of equations may thus be written down from which the values of R_1, R_2 ...... R_{10} may be deduced (see Appendix).

It should be noted that specially wound non-linear potentiometers would be quite suitable for both methods although these are not commercially available.*

Reference

1. K. C. Garner: 'Multi-tapped potentiometers as accurate linear transducers'. *Electronic Engineering*, January 1961.

* CONTROL understands that appropriately shunted and tapped potentiometers are now obtainable from General Controls Ltd, Basildon, Essex.

APPENDIX

The formula for the calculation of the resistor values required for the second method is derived as follows.

Referring to Fig. 2.6, there are m equal segments of fractional length n, m being an even number, so that only $m/2$ segments need be considered as the law f(K) is symmetrical. The potentiometer total resistance is r. Substituting specific values for K in Eq. (2), and equating the result to the resistances as calculated by normal d.c. circuit laws, gives the following equations.

For $K = 0$

$$f(K)_0 = R/4 = nr(\gamma_{m/2} + \gamma_{(m/2-1)} + \ldots\ldots + \gamma_2 + \gamma_1) \quad \text{(A1)}$$

$$\text{where } \gamma_x = R_x/(nr+R_x) \quad \text{(A2)}$$

For $K = n$,

$$f(K)_n = R/4 - nR(1-n) = nr(\gamma_{m/2} + \gamma_{(m/2-1)} + \ldots\ldots + \gamma_3 + \gamma_2) \quad \text{(A3)}$$

For $K = 2n$,

$$f(K)_{2n} = R/4 - 2nR(1-2n) = nr(\gamma_{m/2} + \gamma_{(m/2-1)} + \ldots\ldots + \gamma_4 + \gamma_3) \quad \text{(A4)}$$

For $K = 3n$,

$$f(K)_{3n} = R/4 - 3nR(1-3n) = nr(\gamma_{m/2} + \gamma_{(m/2-1)} + \ldots\ldots + \gamma_5 + \gamma_4) \quad \text{(A5)}$$

etc. or

$$(\gamma_{m/2} + \ldots\ldots + \gamma_2 + \gamma_1) = R/4nr \quad \text{(A6)}$$

$$(\gamma_{m/2} + \ldots\ldots + \gamma_3 + \gamma_2) = [R/4 - nR(1-n)]/nr \quad \text{(A7)}$$

$$(\gamma_{m/2} + \ldots\ldots + \gamma_4 + \gamma_3) = [R/4 - 2nR(1-2n)]/nr \quad \text{(A8)}$$

$$(\gamma_{m/2} + \ldots\ldots + \gamma_5 + \gamma_4) = [R/4 - 3nR(1-3n)]/nr \quad \text{(A9)}$$

etc.

Solving for γ_1, γ_2, etc.

$$\gamma_1 = [R/4 - R/4 - nR(1-n)]/nr = (R/r)(1-n) \quad \text{(A10)}$$

$$\gamma_2 = (R/r)(1-3n) \quad \text{(A11)}$$

$$\gamma_3 = (R/r)(1-5n) \quad \text{(A12)}$$

$$\gamma_4 = (R/r)(1-7n) \quad \text{(A13)}$$

and by induction

$$\gamma_x = (R/r)[1-(2x-1)n] \quad \text{(A14)}$$

and from eq. (A2)

$$R_x = \frac{nr\gamma_x}{1-\gamma_x} \quad \text{(A15)}$$

which from eq. (A14) gives

$$R_x = \frac{nR[1-(2x-1)n]}{1-(R/r)[1-(2x-1)n]} \quad \text{(A16)}$$

which is the general formula for the xth shunt resistor which will provide the desired compensation.

A design simplification is to make both potentiometers of equal resistance, i.e. $r = R$, so that for this special case

$$R_x = \frac{R[1-(2x-1)n]}{(2x-1)} \quad \text{(A17)}$$

If potentiometers of unequal value are used it is, of course, essential that the tapped potentiometer should have a resistance $\geqslant R/4$ when $K = 0$ and $K = 1$. The condition for this is that the pair of segments having the maximum incremental resistance can be achieved in the absence of shunt resistors across these segments.

In the general case considered, the maximum slope occurs across segments 1 and m, and it is necessary to consider the value of r which yields an infinite value for R_1 in equation (A16). This will be the minimum permissible value of r for use with a specified number of segments, and linear potentiometer of resistance R.

Thus for $R_1 \to \infty$ from eq. (A16)

$$\frac{nR(1-n)}{1-R(1-n)/r} \to \infty \quad \text{(A18)}$$

$$\text{or} \quad 1-R(1-n)/r = 0 \quad \text{(A19)}$$

Hence the minimum value of r is given by

$$r = R(1-n) \quad \text{(A20)}$$

The calculation for the example circuit shown in Fig. 2.5 is as follows:

In this example $r = R$ so that equation (A17) is appropriate, i.e.

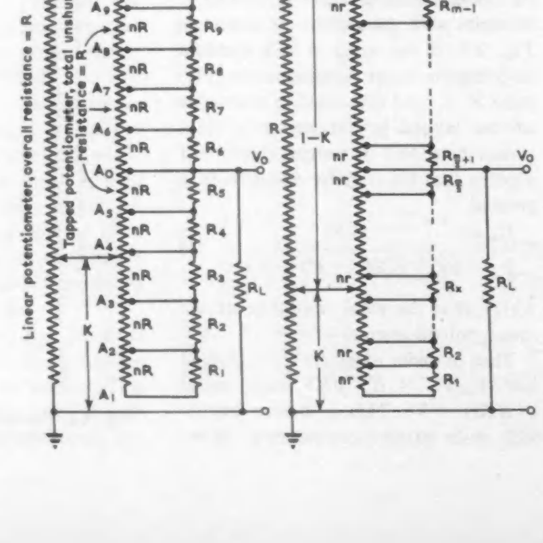


Fig. 2.5 (Left) Example circuit for second method, using two equal linear potentiometer windings and ten shunt resistors

Fig. 2.6 (Right) General circuit for second method

$$R_x = \frac{R[1-(2x-1)n]}{(2x-1)} \quad \text{where } n = 0{\cdot}1.$$

Hence

$$R_1 = \frac{R[1-(2-1)0{\cdot}1]}{(2-1)} = 0{\cdot}90R = R_{10}$$

(by symmetry).

Similarly $R_2 = 0{\cdot}23R = R_9$, $R_3 = 0{\cdot}10R = R_8$, $R_4 = 0{\cdot}042R = R_7$, and $R_5 = 0{\cdot}011R = R_6$. Thus when the value R for the potentiometers has been chosen, the precise values of the shunt resistors may be evaluated.

. . . to VOLTMETERS

Stroboscopic method for digital read-out

In conventional null-balance digital voltmeters, electro-mechanical stepping switches perform a balancing operation between the unknown voltage and a variable reference voltage, and also operate the digital read-out device. The mechanism of such voltmeters is relatively expensive, and the response time is usually limited to about 0·3 s. High cost has tended to discourage the widespread use of digital voltmeters of this kind. The response may be improved by replacing mechanical stepping switches by electronic switches, though this generally results in a further increase in cost.

The Electro-Logic V.1 voltmeter* (Fig. 3.1) uses a stroboscopic technique (patent pending) to give a digital display of a direct voltage. This technique allows a fairly simple form of construction and results in a comparatively low cost instrument. In operation, a reference voltage is continuously varied from zero to maximum by a potentiometer rotating in synchronism with a transparent numbered drum. The reference and input voltages coincide once each revolution, operating a stroboscope lamp which illuminates the appropriate voltage value on the drum.

Fig. 3.2 illustrates the principle of the voltmeter. The unknown input voltage is fed, without amplification, to one grid of a double-triode comparator. For voltages in the range 0–2·5 V, direct connexion is used; a voltage divider provides the necessary attenuation on the higher ranges (0–25 V and 0–250 V). The second grid of the comparator triode is connected to the ramp function output of the linear potentiometer, which sweeps from zero to −2·5 V at a rate of approximately 22 c/s, in synchronism with the numbered drum. When the sweep voltage reaches the value of the unknown input voltage, both grids of the comparator valve are at an equal potential and a switching transistor is operated, producing a fast pulse with rise time of 3 μs. This 'equality pulse' is shaped by an emitter-coupled transistor 'trigger' circuit to produce a 'trigger' pulse.

There are two possible modes of operation of the voltmeter. In the so-called 'quasi-digital' mode, the 'trigger' pulse fires a thyratron which operates the stroboscope lamp. The

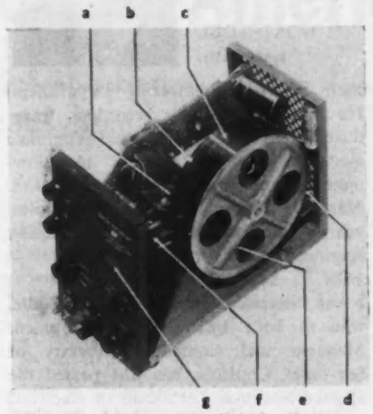


Fig. 3.1 Stroboscopic digital voltmeter: (a) stroboscope lamp; (b) clock-pulse track; (c) number track; (d) drum; (e) motor; (f) lens; (g) ground glass screen

thyratron output is increased to the required level by a step-up transformer. Hence, coincidence of the input and sweep voltages causes a light flash which illuminates the appropriate number on the drum, projecting it on to a ground-glass viewing screen. Since the drum rotates in synchronism with the slider of the sweep potentiometer, the instantaneous angular position of the slider corresponds to one of the 250 equally spaced numbers on the drum periphery. When the slider is at the start of the potentiometer track (i.e. zero reference volts) the numbers 000 are interposed between the lamp and the screen; as the slider rotates the interposed number progressively increases up to a maximum of 250, which coincides with the end of the potentiometer track (2·5 volts).

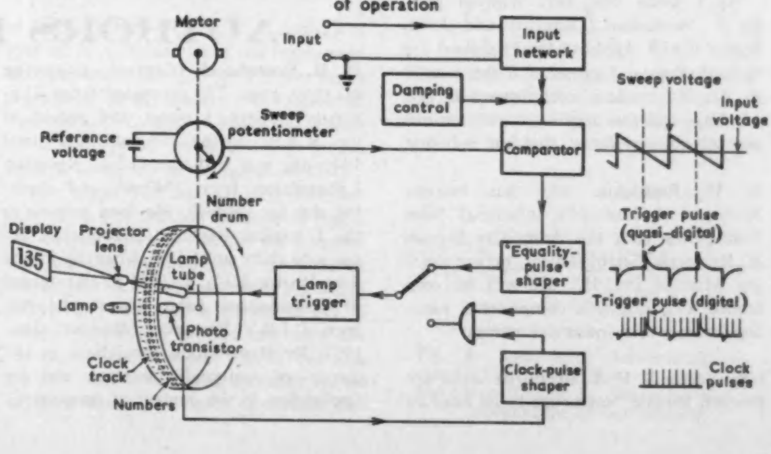
The precision of the voltage measurement depends on the linearity of the sweep potentiometer and on the triggering speed of the stroboscope lamp and associated circuitry; the resulting accuracy is claimed to be better than 0·5%.

In this 'quasi-digital' mode, an input voltage change causes the numbers to move smoothly through the viewing aperture, facilitating the observation of a rate of change of voltage, and permitting interpolation between numbers. In the 'digital' mode, 'gating' of the trigger pulse is performed by superimposing clock pulses obtained photo-electrically from a clock track on the drum, so that the projected numbers remain stationary in the viewing aperture. Each number on the drum has a corresponding transparent clock mark, through which light is projected on to a photo-transistor when the number is opposite the stroboscope lamp. Symmetrical clock pulses are produced by an emitter-coupled shaping circuit.

The response time of the read-out is determined by the time taken for one revolution of the drum, *i.e.* about 45 μs.

The high-speed sweep potentiometer has a continuous track of conductive plastic. A life expectancy of more than 10^8 operating cycles is claimed for this potentiometer, which is made as a readily replaceable unit.

Fig. 3.2 Schematic diagram of voltmeter. The wave-forms to the right of the diagram illustrate the difference between the 'digital' and 'quasi-digital' modes of operation



* Marketed in the U.K. by Scientific Furnishings Ltd, Poynton, Cheshire.

EMBLETON GREENFIELD
industrialists

DAVIS
analyst

PEOPLE IN CONTROL

by Staffman

NORTHEDGE
systematist

Three new Directors have been appointed to the Board of Westool Ltd, **D. Riddell,** Chief Engineer, **D. L. Shand,** Works Manager and **A. G. Why,** Secretary and Accountant. Riddell joined Westool in 1946 and became Chief Engineer in 1954. Shand was appointed Works Manager in 1958, and Why first joined the company in January 1959. Commenting, **Angus Hunking,** Managing Director said, 'these new appointments, all of them fairly young men, will greatly strengthen our top management team. . . .' Hunking himself was elected to the Board of the Warner Electric Brake & Clutch Co, Beloit, Wisconsin,

RIDDELL
U.K. board

HUNKING
U.S. board also

U.S.A., recently. Westool, of course, manufacture Warner electro-magnetic clutches and brakes for automatic machine control.

As I write this, two Westool men, **C. E. Mackellar** (Director) and **J. B. Bailey** (Chief Applications Engineer) are visiting Russia. I gather that the idea is to discuss modern techniques in coil winding, and the application of various control equipment to Russian industry.

E. W. Embleton, who has become Manager of Mullard's Industrial Sales Force, was with the Admiralty Signals & Research Establishment before joining Mullard in 1953. He will be concerned with magnetic components, semiconductors, and industrial valves.

I hear that S. E. Laboratories have appointed **Ronald Northedge** to be head of their Systems Engineering Department. He is responsible for recorders, transducers, pressure valves and complete electronic systems, and of the flowmeters produced by Meterflow Ltd. Northedge was at Rolls-Royce for eleven years, becoming Senior Instrumentation Engineer in the Rocket Division.

I was interested to learn that **R. Mudie,** who is both Instrument Development Manager and Company Secretary of Servomex Controls, has just passed the Higher National Certificate in electrical engineering. Apparently **Richard Steel,** Managing Director of Servomex, believes that his policy 'of paying people to work four days and study the fifth day, whilst expensive to the company, has resulted in increased efficiency'.

I see that the Brit.I.R.E. have shared the Charles Babbage Award for an outstanding paper on electronic aspects of computers between Dr **M. Prutton** of I.C.T., and Dr **T. B. Tomlinson** of Southern Instruments. Prutton's paper was entitled *Ferro-electrics and computer storage,* and Tomlinson's, *Switching circuits using bi-directional non-linear impedances.* Tomlinson joined Southern Instruments last spring as Chief Engineer, and is also responsible for design and development at Drayton-Southern. He was a laboratory demonstrator at the Cavendish, head of television-receiver development at Sobell, and a lecturer in electronics at Southampton University for six years. He then joined G.E.C. to work on solid-state physics prior to going to the G.E.C.-I.C.T. subsidiary, Computer Developments Ltd.

Incidentally, **H. M. Davis,** who joined Southern Analytical as Chief Engineer and Director recently, was with the Ministry of Supply's Chemical Inspectorate. He was seconded to the U.K.A.E.A., and became head of the Physical Methods Section at Woolwich Arsenal where he worked on instrumental methods of analysis.

T. E. Greenfield, who has been appointed Sales Development Manager of the Industrial Process Control Division of Gresham Automation, has had an interesting career. He was with J. Langham Thompson, and joined G.E.C., Stanmore, for work connected with flight instrumentation trials. He then returned to J.L.T. as General (Technical) Sales Manager until 1957, when he joined English Electric Aviation. There he was head of quality control for guided weapon production at Stevenage, and Test Project Engineer for the Thunderbird II. Other Gresham news includes the award of a first prize to **Allen J. Coleman** for his paper *A random observation work study,* in the 1960 Group Apprenticeship Competition of the Engineering Industries Association. A. J. Coleman is, of course, the son of **John P. Coleman,** Chairman of the Gresham Lion Group.

AUTHORS IN CONTROL

H. H. Rosenbrock (*Control engineering in 1960,* page 77) graduated from University College, London, and served in the R.A.F. during the war and until 1946. He was with the G.E.C. Research Laboratories from 1947–48, and teaching during 1948–49. He then moved to the Electrical Research Association, remaining there until 1951 when he joined John Brown & Co. In 1954 he transferred to Constructors John Brown and has been C.J.B.'s Research Manager since 1957. Dr Rosenbrock specializes in the theory of automatic control and its application to the control of processes.

R. N. Aldrich-Smith (*Controlling the production of nylon yarn,* page 79). See page 129, December 1960.

P. F. Blackman (*Pole-zero approach to system analysis,* page 83). See page 126, November 1960.

Denis Taylor (*Instrumentation of nuclear power stations,* page 90). See page 129, December 1960.

A. J. Morton (*Boiler feed discharge systems under changing load,* page 95). See page 126, November 1960.

This news-letter from our special correspondents in the United States includes a survey of work on the human operator as a unit in a control system

Look at America

This month: dual-mode control—backlash—positive feedback—human operators—electromechanical system analysis

Dual-mode servomechanisms

The stability of an important class of control systems has been discussed by Gibson and McVey in their paper on dual-mode servomechanisms (*1*). The term dual-mode refers to the ability of the servo to utilize proportional control for small error signals, and relay control for large error signals, as shown in Figs. 1 and 2. Relay action is easy to implement, and can provide fast response; the proportional region is used to eliminate the steady-state limit cycle and hence steady-state error resulting from pure relay control.

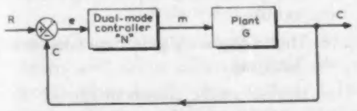


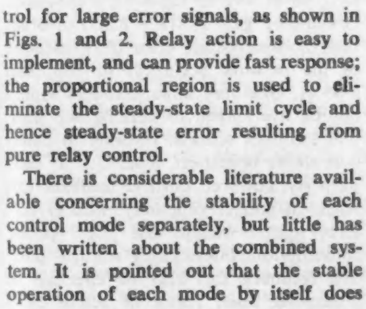
Fig. 1 Block diagram of dual-mode system

There is considerable literature available concerning the stability of each control mode separately, but little has been written about the combined system. It is pointed out that the stable operation of each mode by itself does not guarantee stable operation of the dual-mode servo. In order to determine stability of the dual-mode system, a describing function technique is used. From Fig. 1 it is possible to write

$$\frac{C}{R}=\frac{NG}{1+NG}$$

where N is the describing function representation of the non-linear controller. When $1+NG=0$, an instability is possible and a limit cycle oscillation can be maintained. Therefore, it becomes necessary to see whether or not $G = -1/K_{eq}$, where K_{eq} is the equivalent gain of N as found from the fundamental component term of the Fourier series representation of m when e is sinusoidal. Therefore, if G and $-1/K_{eq}$ are drawn on a polar plot, an intersection represents a condition of marginal stability.

Fig. 2 A typical dual-mode controller input-output characteristic



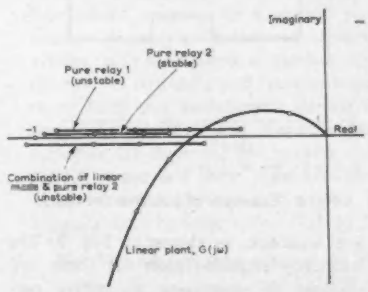


Fig. 3 Polar plot of linear plant in combination with three different controllers

The linear function G is a function only of $j\omega$. For the non-linearity of Fig. 2 the output phase is zero at all frequencies, but the amplitude, K_{eq}, depends on the amplitude of the incoming signal, e. A typical polar plot is shown in Fig. 3 where $-1/K_{eq}$ is plotted not only for the dual-mode case (i.e. Fig. 2) but also for two pure relays with different values of dead band. The figure illustrates that the linear plant in combination with a pure relay may or may not be stable. However, if a stable relay controller is used in combination with a linear controller to form the dual-mode scheme, the behaviour may not be stable at certain amplitudes.

Servomechanisms with backlash and friction

An interesting analysis of servos having negligible inertia loads, but with significant Coulomb friction and backlash, is presented by Pastel and Thaler (*2*). Such a system, shown in Fig. 4, is commonly used in instrument servos, where the load might be a potentiometer wiper arm.

The motor-amplifier transfer function is assumed to be

$$\frac{\theta_m}{E}=\frac{K}{J_m D^2+f_m D}\,;\ D=\frac{d}{dt} \qquad (1)$$

During the times when the backlash is taken up, $\theta_c=\theta_m$, and the system behaves in a perfectly linear fashion. Assuming, for the moment, that $C=0$, the linear transfer function becomes

$$\frac{\theta_c}{\theta_r}=\frac{K}{J_m D^2+f_m D+K} \qquad (2)$$

The system's behaviour is described by its phase plane trajectory in Fig. 5. If the system starts out at some point M, with its backlash taken up, it will pro-

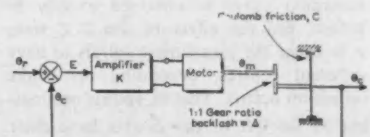


Fig. 4 Instrument servomechanism: motor has inertia J_m and viscous or electrical damping f_m. The value of C is independent of load velocity

gress to point N, at which time the motor velocity reverses, but the output velocity does not, due to the presence of the backlash. Therefore the output remains at N while the motor builds up velocity according to Eq. (1), with E assuming the constant value E_N. As soon as $\theta_m = \triangle$ (the amount of backlash), the motor again begins to drive the load, which immediately jumps from zero velocity to the velocity of the motor. This is represented by going from point

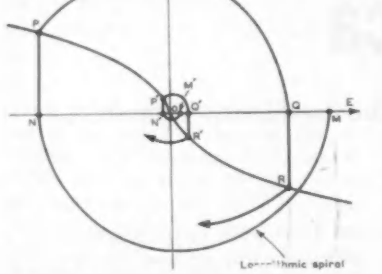


Fig. 5 Phase plane trajectories for system of Fig. 4 with C = 0

N to P in Fig. 5. The overall behaviour is then linear from P to Q, but at Q the sequence of events just described repeats itself. The transition points P are uniquely determined by the use of Eq. (1), knowing that $E = E_N$ and $\theta_m = \triangle$.

It can be seen that the shape of the locus of transition points, P, determines system stability. For the points $M\,N\,P\,Q\,R$, both the error and error-rate cyclically decrease, but for the points $M'\,N'\,P'\,Q'\,R'$ the error and error-rate cyclically increase. A limit cycle occurs when $ON = OQ$ (or $ON' = OQ'$). Using this as a criterion of stability, and realizing that shapes of both the logarithmic spirals and the transition locus are determined by system constants, it is shown that a limit cycle cannot exist if $\zeta \equiv \dfrac{f_m}{2\sqrt{KJ_m}} > 0{\cdot}29$, regardless of the amount of backlash.

When Coulomb friction C is added at the output shaft, Eq. (1) is still valid when the backlash is not taken up, but when it is, Eq. (2) must be modified to

$$J_m D^2\theta_c + f_m D\theta_c + K\theta_c \pm C = K\theta_r,$$

where C takes the sign of $D\theta_c$.

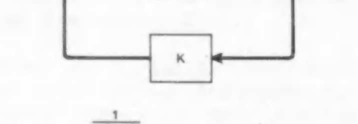
In constructing phase plane trajectories for this system it is noted that the transition curve is obtained exactly as before, but the effect of the $\pm C$ term is to cause the logarithmic spirals to have different centres, depending on where transition occurs. That is, spirals originating to the left of the $\dot{E}$ axis have their centres at $-C/K$, whereas spirals originating to the right of the $\dot{E}$ axis have their centre at $+C/K$. Since this causes the trajectory to 'spiral in' more quickly, the effect of Coulomb friction acting on the load is seen to be generally stabilizing, and can be used to eliminate limit cycles in systems that are otherwise too lightly damped.

Positive feedback in active compensation networks

An often misunderstood concept in control theory is that of 'positive feedback'. To many, the words 'positive feedback' are immediately associated with system oscillation or instability. That this association can be totally wrong is well illustrated in Fig. 6. Thus, unity positive feedback around a simple lag results in the generation of an integrator with an integration rate equal to the reciprocal of the original time constant.

As pointed out by W. Scharf (*3*), positive feedback can be extremely effective in the generation of active lead/lag compensating networks. *Active* compensation, as compared to passive compensation, is generally desirable when flexibility, lack of attenuation, and limitation to non-inductive elements are required. According to Scharf, a stable low-gain transistorized differential amplifier serves as a useful and simple building block around which active networks can be built.

Active lead/lag networks can be generated using either positive or nega-



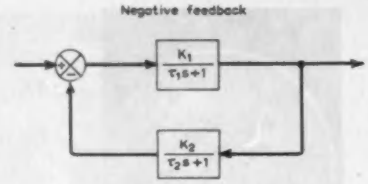
$$\frac{C}{R} = \frac{\dfrac{1}{\tau D+1}}{1-\dfrac{K}{\tau D+1}} = \frac{1}{\tau D+1-K}$$

$$\text{If } K = 1;\ \frac{C}{R} = \frac{1}{\tau D}$$

Fig. 6 Example of positive feedback

tive feedback, as shown in Fig. 7. The frequency response plots for these two schemes of generating an active network are shown in Fig. 8. These plots show the following advantages inherent in the positive feedback network:

(*a*) Unattenuated forward loop gain at

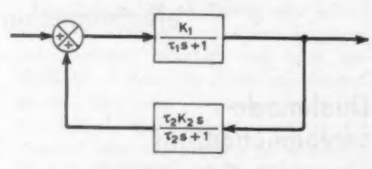


$$\frac{e_o}{e_i} = \frac{\dfrac{K_1}{\tau_1 s+1}}{1+\dfrac{K_1K_2}{(\tau_1 s+1)(\tau_2 s+1)}}$$

But $\tau_1 \approx 0$; (ie., Transistor time constant $\tau_1 \approx 1\mu$sec)

$$\therefore \frac{e_o}{e_i} = \frac{K_1}{1+K_1K_2}\ \frac{\tau_2 s+1}{\left(\dfrac{\tau_2 s}{1+K_1K_2}+1\right)}$$

Fig. 7 Schemes for generating 'active' lead/lag compensation: above, negative feedback system; below, positive feedback system



$$\frac{e_o}{e_i} = \frac{\dfrac{K_1}{\tau_1 s+1}}{1-\dfrac{\tau_2 K_1K_2 s}{(\tau_1 s+1)(\tau_2 s+1)}}$$

$$\tau_1 \approx 0$$

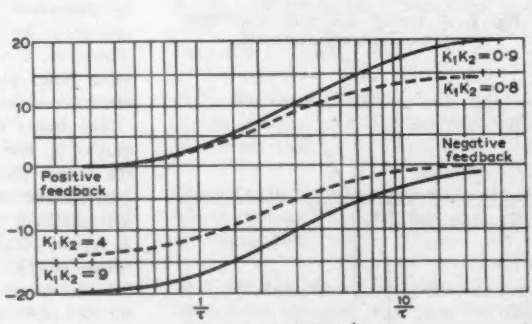
$$\therefore \quad \frac{e_o}{e_i} = \frac{K_1(\tau_2 s+1)}{(1-K_1K_2)\tau_2 s+1}$$

low frequencies (independent of lead/lag ratio).

(*b*) High frequency gain dependence on the lead/lag ratio.

The largest single disadvantage of the negative feedback scheme is the requirement that the steady-state open-loop gain (K_1), be at least 20 times the steady-state closed-loop gain $K_1/(1 + K_1K_2)$ in order that the steady-state error (E, a measure of the network accuracy) be less than $0{\cdot}05\ e_i$. One very important fact should not be overlooked concerning the positive feedback scheme. In order to maintain stable operation, $K_1K_2 < 1$. If used properly, however, positive feedback can result in greater simplicity, smaller volume, lighter weight, and lower power consumption. Interestingly enough, positive feedback can also be effective in generating other forms of active com-

Fig. 8 Frequency response plots for positive and negative feedback schemes ($K_1 = 1$)



pensation networks (e.g., second-order 'lead/lag' networks) in certain applications requiring more sophisticated compensation schemes.

Dynamics of human operators

In control situations where the control problem is simple and requires good dynamic response, high power output, continuous performance for long periods of time, or operation in unusual and 'stressful' environments, completely automatic control of machines is generally more economical and reliable than human operation. Yet in a great many situations it is found that the human operator can out-perform his electronic or mechanical counterpart. Man seems

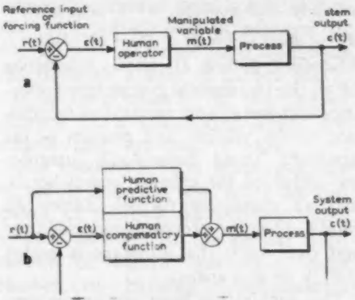


Fig. 9 Representation of one-dimensional control tasks: **a** (above) compensatory; **b** (below) pursuit displays (from Sheridan: Ref. 4)

to have remarkable abilities to perceive, learn and adapt in a changing environment while performing a control function. These qualities are extremely difficult to build into a non-human controlled system. Because of his attributes, man is expected to continue and possibly even expand his activity as an important control element.

During the past 15 years much research has been directed toward an objective understanding of man-operated control systems (*4*). Motivation for this research has partly resulted from the practical necessity that certain facts must be known about human behaviour before man-operated systems can be successfully engineered. Further, it has been necessary to study how a human behaves when confronted with a well-defined task in order to learn more about his basic performance as a part of a real physical system. The study of human behaviour and performance has justly been viewed from many aspects, from the points of view of the psychologist or physiologist, the design engineer, and the systems engineer. The engineer has necessarily felt a need for some common language in which to express the behaviour and performance of both human and physical system components. To this end, much work has been directed toward the development of mathematical models for

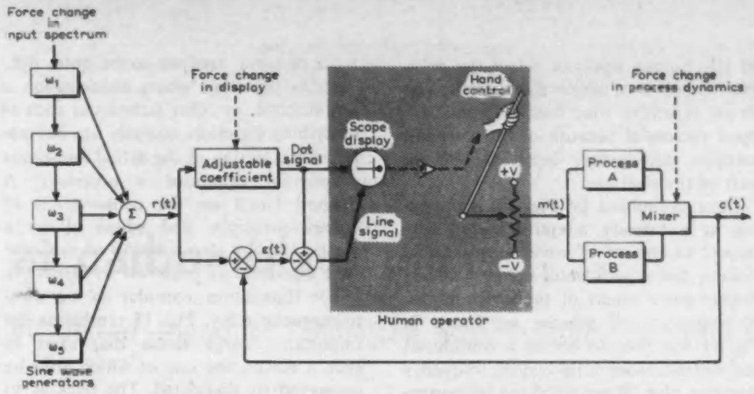


Fig. 10 Human operator with time-varying parameters (from Sheridan: Ref. 4)

human control elements to be used in the same sense that mathematical models of electrical, mechanical, and chemical elements have been used as building blocks for analysis and synthesis of control systems.

McRuer and Krendel (*5*) have provided a comprehensive review of the literature describing efforts to establish suitable mathematical descriptions of human operator dynamic response and performance in continuous, closed-loop control systems. Typical control situations that have been studied have utilized a visual input and a manual output, e.g., a simple tracking task. The majority of the investigations have been based on the simple control-system models of Fig. 9. In Fig. 9a the operator sees only the system error, whereas in Fig. 9b he sees both the reference input and the error.

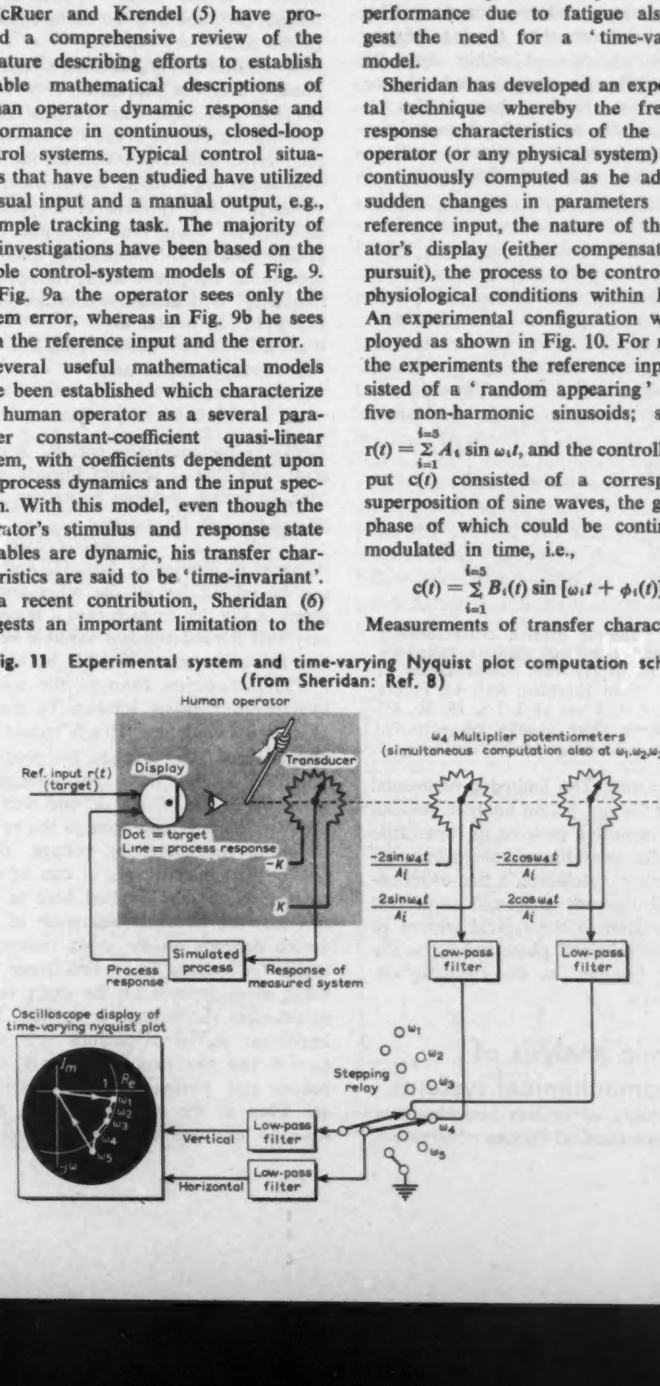
Several useful mathematical models have been established which characterize the human operator as a several parameter constant-coefficient quasi-linear system, with coefficients dependent upon the process dynamics and the input spectrum. With this model, even though the operator's stimulus and response state variables are dynamic, his transfer characteristics are said to be 'time-invariant'. In a recent contribution, Sheridan (*6*) suggests an important limitation to the 'time-invariant' model of the human operator. If the human operator learns or 'adapts' in time, and if the transient period of behaviour is of interest, then an inherently 'time-variable' model is said to be required. Decays in operator performance due to fatigue also suggest the need for a 'time-variable' model.

Sheridan has developed an experimental technique whereby the frequency response characteristics of the human operator (or any physical system) can be continuously computed as he adapts to sudden changes in parameters of the reference input, the nature of the operator's display (either compensatory or pursuit), the process to be controlled, or physiological conditions within himself. An experimental configuration was employed as shown in Fig. 10. For most of the experiments the reference input consisted of a 'random appearing' sum of five non-harmonic sinusoids; so that $r(t) = \sum_{i=1}^{i=5} A_i \sin \omega_i t$, and the controlled output $c(t)$ consisted of a corresponding superposition of sine waves, the gain and phase of which could be continuously modulated in time, i.e.,

$$c(t) = \sum_{i=1}^{i=5} B_i(t) \sin [\omega_i t + \phi_i(t)]$$

Measurements of transfer characteristics

Fig. 11 Experimental system and time-varying Nyquist plot computation scheme (from Sheridan: Ref. 8)



of the human operator when the reference input is a single sinusoid (or any single repetitive time function) have not been successful because of an unusually complex anticipatory behaviour on the part of the operator.

Once the subject (in Fig. 10) is operating at a 'steady adaptive state' with respect to one set of environmental conditions, the experimenter could suddenly change some aspect of the environment. A computational scheme as shown in Fig. 11 was used to obtain a continuous and instantaneous time-varying frequency response plot (Nyquist) of the time-varying system. A typical plot is shown in Fig. 12. With the assumption that all elements of the measured closed loop system were linear (found to be a reasonable assumption) the open loop characteristics of the human operator could be computed. Experimental results indicated that the experienced operator changes his transfer characteristics (during adaptation) consistently and within about 30 seconds. When an inexperienced operator is learning, results showed that a change in the operator's characteristics may extend over ten minutes, with a fairly high unsteady fluctuation of

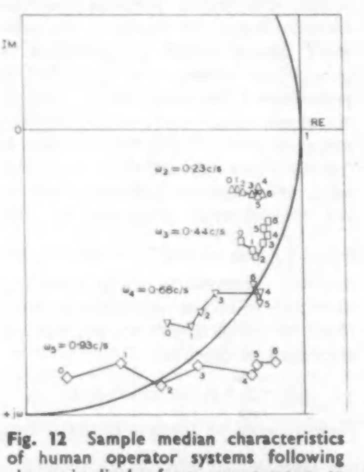


Fig. 12 Sample median characteristics of human operator systems following change in display from compensatory to pursuit (from Sheridan: Ref. 4). Points 0, 1, 2, 3, 4, 5 are at 0, 7·5, 15, 30, 45, 60 seconds after change respectively; point 6 is average for next minute

characteristics. The limited experimental evidence did not permit analytic generalizations regarding patterns of time-variation of the quasi-linear human operator characteristics. However, a first-order exponential lag was suggested as a first approximation to the typical pattern of change in gain and phase values, as the operator 'adapts' to the changing environment.

Dynamic analysis of electromechanical systems

The presence of certain non-linearities in electromechanical systems often causes their dynamic analysis to be quite difficult. In situations where linearization is not suitable, or other techniques such as describing function analysis are not applicable, solution of the actual non-linear differential equations is necessary. A method based on the conservation of energy principle, and which allows a digital step by step solution of the relevant equations, is proposed by Hyink (9).

For illustration, consider an a.c. electromagnetic relay. Fig. 13 represents the important energy terms that exist in such a device, the sum of which must be conserved or dissipated. The trick is to represent all the energy relations involved in terms of small increments of time, δt. As examples consider:

1. Electrical energy input =

$$\int_0^t e\, i_c\, dt = W_e \qquad (1)$$

where e is the voltage applied to the magnet coil, and i_c is the current flowing in the coil.

Now assume that the current, i_c, changes linearly over the interval δt, $i_c = i_{c0} + (\delta i_c/\delta t)t$ and that the voltage acting over the interval δt is the average value, $(e_0 + e_t)/2$. Subscript *0* denotes the variable at the beginning of the interval, and subscript *t* the variable at the end of the interval. Note that the value of e at any time is an independent quantity, determined by power main voltage and frequency. With the above considerations, Eq. (1) can be written as

$$W_{et} = W_{e0} + (e_0 + e_t)(i_{c0} + \delta i_c/2)\delta t/2 \qquad (2)$$

2. Energy loss in coil =

$$\int_0^t i_c^2 R_c\, dt = W_c$$

Assuming the coil resistance, R_c, is constant, and that i_c changes linearly with time, as before, this can be written as

$$W_{ct} = W_{c0} + R_c\,[i^2_{c0} + i_{c0}\delta i_c + (\delta i_c)^2/3]\delta t \qquad (3)$$

Expressions similar to Eqs. (2) and (3) can be set up for all the other energy terms in Fig. 13. In each case it is necessary that the independent variable be δt, and the independent variable be δi_c.

The incremental form of the energy expressions suggests solution by means of a digital computer. This is indeed the method used. To visualize the program required, assume the input voltage is given by $e = \sqrt{2}\,E \sin \omega t$, and that all the W terms are zero prior to the application of the energizing voltage. Then for the first interval, δt_1, e_t can be calculated. Note that implied here is the fact that the transient behaviour of the device depends on the exact instant at which the voltage is applied, since the value of e_0 depends on the exact value of ωt when the voltage is applied. The important initial conditions are that $i_{c0} = 0$ and the magnet force is zero before and during the first interval, δt_1. Then at the end of δt_1 it is possible to evaluate the energy equation represented by Fig. 13. the result is an expression which can be solved for δi_c. This provides the i_{c0} for the interval δt_2 and allows calculation of the magnet force acting during δt_2. Subtracting the friction and spring forces from the

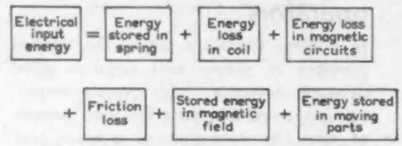


Fig. 13 Important energy terms in an electromagnetic device

magnet force yields the net acceleration force acting on the armature,

$$F_n = Ma$$

Assuming the acceleration is constant over δt_1 we have for the armature velocity and position, $\delta V = a\delta t$, and

$$\delta X = a(\delta t)^2/2 + V_0\delta t = (V_0 + \delta V/2)\delta t$$

Therefore, finding δi_c allows calculation of all the incremental energy terms, electrical, magnetic, and mechanical, in addition to the velocity and position of the armature. These incremental quantities are added to the existing energy totals, and an expression for δi_c *during* δt_2 results. Then the process is repeated over and over until the armature is sealed (i.e., X = gap space).

The method has been applied to predict armature velocity/time characteristics for a specific device. Measured and calculated results appear to agree quite well, but it is apparent that the calculated solutions are very sensitive to the initial value chosen for ωt.

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Sequence control at carbon black plant

Bag-filter operation at United Kingdom Chemicals electronically controlled

CARBON BLACK IS A FINE POWDER OF similar appearance to soot. However, it is finer than soot, contains much less foreign matter and, being very pure and of small particle size, is frequently referred to as colloidal carbon. The particle size is between 10 and 120 μm, a range covering about fifty different grades of carbon black. It is used mainly by the rubber industry as a reinforcing agent for natural and synthetic rubbers.

The modern carbon black industry started in America soon after the discovery of natural gas. At that time, production involved the partial combustion of natural gas on a large number of batwing type burners against lengths of channel iron, the black being scraped off the channels by hand at first, and later by mechanical means. This process was most expensive of feedstock, yields being lower than 5%.

In the early 1930's, a method of producing carbon black by the partial combustion of gas in an enclosed continuously operating furnace was devised. Controlled amounts of gas and air were fed into a refractory-lined furnace and decomposed, the resultant black-laden gases being piped away to cyclones where the gas and black were separated to some degree.

During and after the second world war, many advances were made in the production and collection of carbon black. However, alternative outlets were found for natural gas, leading to price increases, and this resulted in the development of furnaces using liquid hydrocarbons to enrich the gas.

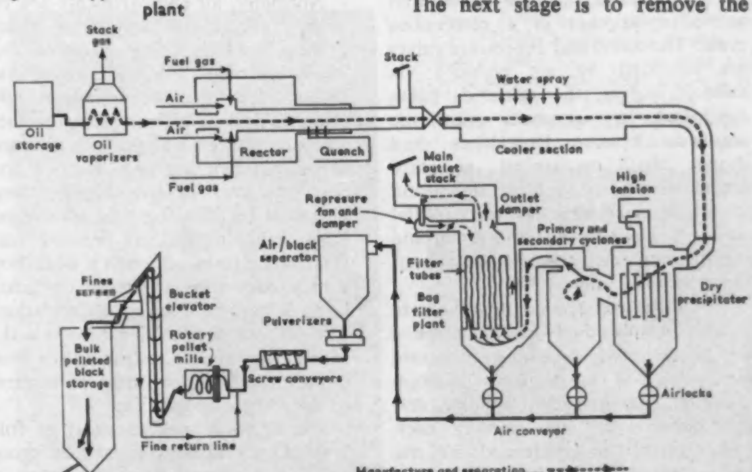
Separation and collection techniques improved continuously with the development and increased loadings of furnaces. Collection plants were enlarged and furnace exit-lines connected into electrostatic precipitators followed by multiple banks of cyclones and wet scrubbers. This raised the efficiency of collection to between 80% and 90%.

The Port Tennant plant

In 1950, United Kingdom Chemicals constructed a carbon black plant for the production of reinforcing furnace blacks at Port Tennant, Swansea. The separating and collection plant consisted of primary electrostatic precipitators, and primary and secondary cyclones. Later, during 1953–54, a secondary precipitator and cyclone bank and wet scrubbers were added. This arrangement gave a product-collection efficiency of between 90% and 95%, a level which, although satisfactory in unpopulated areas, meant that the amount of carbon-black discharge from the main stack could be a source of nuisance in a built-up area such as Port Tennant. In 1956–57 a bag-filter plant was added after the secondary cyclone banks, and this effected an almost complete clean-up.

In 1958 it was decided to install a new plant for the manufacture of fine-particle, higher-quality furnace blacks. In view of previous experience, it was decided that the collection plant should consist of large-diameter cyclone banks, followed by a multi-chamber bag-filter plant which should operate automatically. This would eliminate the need for precipitators and wet scrubbers. The general arrangement will be apparent from Fig. 1, which is a production flow sheet for a typical carbon black-from-oil plant.

Fig. 1 A typical carbon black-from-oil plant



Bag-filter operation

At this point the problem of continuous operation and automatic control of the bag-filter plant arose. The size of these bag-filter units depends upon the volume of gas to be handled, and the usual compartment houses several hundred glass-cloth filter bags of 5-in diameter by 126-in long. Each compartment consists of a rectangular bag-chamber having a tube plate as a base to which the bottoms of the bags are attached. The tops of the bags are attached to a shaker bar in the roof. Under the bag chamber is a conical hopper, with a star valve at its base, which feeds into a conveying system.

On reference to Fig. 2 (a basic arrangement of two compartments only) it will be seen that carbon-black laden gases enter the chamber through an inlet pipe and pass upward through the bags to the clean side. The carbon black having been removed, the clean gases pass through an automatically air-operated valve into a main outlet pipe. An exhaust fan keeps the pressure within this outlet main slightly below atmospheric and so passes the gases forward to a main stack for discharge to atmosphere.

The next stage is to remove the

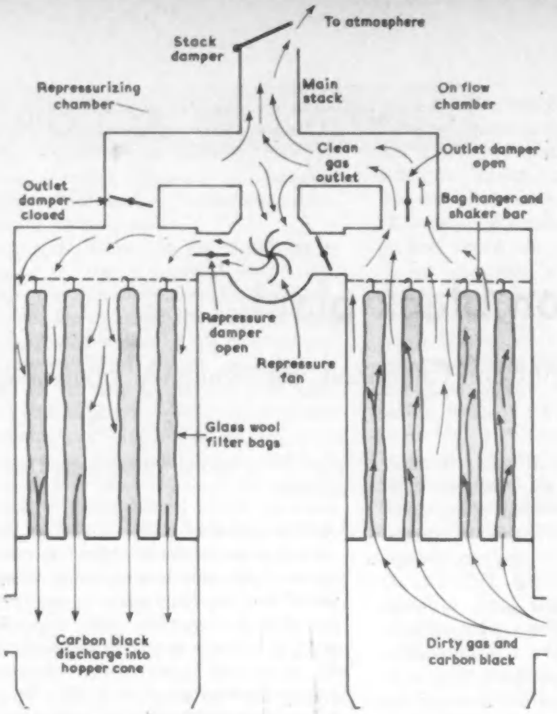


Fig. 2 Basic diagram showing operation of a two-compartment bag-filter scheme

carbon black from the filter bags. A repressure fan takes clean gas from the outlet main and passes it into a common repressure main, the latter being connected by pipes through air-operated valves into each bag-filter chamber—but on the 'clean' side. In operation, the several compartments operate on an automatic time cycle with a given period on stream. At the end of the stream period, the outlet valve closes and the repressure valve opens, so allowing clean gas into the clean side of the chamber. This passes through the bags, from the clean to the dirty sides, and so loosens the carbon black built-up within the bags. The black then falls into the hopper. Final cleaning of the bags is by shaking during the repressure period.

Controlling the bag filters

The compartments are repressured one after another in a continuous cycle. The outlet and repressure valves are operated by air pressure via solenoid valves, the solenoids being controlled by automatic electronic sequence timers. Experience had shown that mechanical sequence timers were liable to break down and to jam, thus causing two main outlet valves to close at the same time, and creating surges of pressure throughout the collecting system.

It will be appreciated that the rate at which the product—carbon black—can be collected, depends on the rate at which gases can be passed through the filter chambers continuously, and this depends on how rapidly each compartment can be cleaned—i.e. the end product extracted and the filter left in an efficient condition. As carbon collects in each filter, there is an increasing resistance to the flow of gas, a rise in pressure in the gas flow line, and a reduction in the rate at which the carbon particles can be collected. Therefore, the control of the cleaning cycle of each filter compartment, and the instantaneous change-over from one compartment to the next undergoing the cleaning cycle, affects the yield of carbon black.

United Kingdom Chemicals consulted Sargrove Electronics on this problem, and the latter designed and installed a 'Countec' filter-control unit, based on steplessly variable electronic timing control. The installation includes a mimic panel which incorporates indicators for gas pressures and temperatures at various points; indicators also show each filter compartment's position within the cycle.

Normally, all compartments are on stream except the one from which carbon black is being extracted, the controller regulating the opening and closing of all the pneumatically operated valves in the system, together with the shaker motors. The moment a compartment has been cleaned and comes back on stream, the next compartment for cleaning goes off stream. This maintains the gas pressure reasonably uniform, although it does drop a little each time a cleaned compartment is brought back into circulation. The process of collecting carbon within the bags, and so restricting the flow in each filter compartment on stream, is, of course, progressive.

The cycle of operations is as follows. As a cleaned compartment goes back on stream, the exhaust valve of the next compartment to be cleaned closes, thus stopping the flow of gas and tending to equalize the pressures in the compartment between the dirty and clean sides of the bag filter. Almost immediately (after about 3-s delay) the repressure valve opens to force clean exhaust gases into the clean sides of the chamber, so reversing the normal pressure condition and causing the filter bag to collapse. Repressurizing continues for a short time, the optimum being ascertained by experiment and the time controls for each compartment being adjusted individually. When the repressure valve closes, thus permitting the pressures in the compartment to equalize, the slug of carbon in the bag drops to the bottom of the compartment.

Although this repressurizing removes most of the carbon black, it does not necessarily ensure that the collecting bag is really clean. A shaker motor is therefore operated to ensure that the bags are thoroughly shaken. This reduces the period during which the compartment is out of circulation for cleaning. The shaking period is adjusted to the minimum which gives adequate results. After allowing a further period for everything to settle down, the exhaust valve opens to permit the black-laden gases to flow again through the compartment.

It follows that there are four electronic timers for each compartment. Cancelling switches are fitted so that in the event of any trouble occurring in a filter compartment, that unit can be isolated from the cleaning cycle or, if it is desired to run without the shaker motor, on any one compartment, this can also be switched out. If this is done, the whole cleaning cycle is shortened automatically by the amount of time normally devoted to that compartment or its shaking period. Any adjustment to any time interval of any one compartment adjusts the total time of the cleaning cycle automatically, so that the production engineer can operate his plant at the optimum efficiency. Normally the cleaning cycle is continuous, i.e. when the filters in all compartments have been cleaned, the cleaning process starts again. However, if, when all compartments have been cleaned, the gas pressures remain low enough for them all to remain on stream, it is obviously not necessary to recommence the cleaning cycle immediately. For this purpose a 'dwell' timer has been incorporated.

At Port Tennant, the several sets of four electronic timers (four per chamber) are contained in a dust-proofed compartment, and visible through a glass door. The isolating switches are outside the compartment, but the

other controls are completely enclosed as they do not require attention once their optimum settings have been determined. Each timer is of the plug-in type, and three spares are held within the compartment so that they can be replaced easily and with little or no interruption to the process cycle.

Damper-valve operation is by pneumatic cylinders controlled through double-pole magnetic valves, whilst the shaker motors are switched by the timers through three-phase contactors. The opening and closing of the damper valves under the control of the timers is also indicated on the mimic panel.

The filter control unit was installed at Port Tennant during April and May 1960, and the new plant went on stream in June. According to United Kingdom Chemicals, it has operated perfectly since that date.

Acknowledgement

Thanks are due to Major H. Hardy of United Kingdom Chemicals Ltd, Port Tennant, for much of the material on which this article is based.

CONTROL IN ACTION

Automatic furnace-charging

Pneumatically-operated furnace loading and unloading at Smiths Stampings of Coventry

A FRANKLINS ROTARY-HEARTH FORGING furnace used by Smiths Stampings Ltd, Coventry, is fitted with an automatic loading and unloading system. Designed and manufactured by Hymatic Engineering, the automatic equipment is operated by compressed air. The furnace, which is oil-fired and intended for operation at up to 1300°C, preheats steel billets prior to forging, and its burners are controlled automatically from the temperature of the billets. As the burners fire tangentially round the working space, the unloading arm is obliged to work directly in the path of one of the burners.

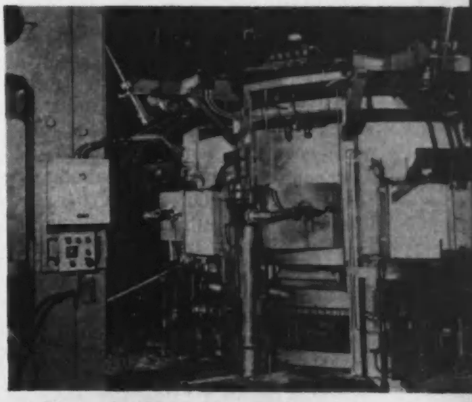
The hearth of the furnace is automatically indexed round a predetermined distance by a pneumatically operated ratchet-and-pawl mechanism operated by signals from the Hymatic system. The jaws of the handling equipment cater for billets from 3½ in to 6 in square, up to 18 in long and weighing from 30 to 104 pounds. The throughput of the furnace is controlled at 35 cwt an hour.

The doors of the furnace are pneumatically operated, and open downwards so leaving the area above and around the furnace clear for the loading and unloading mechanisms. The latter consist of two mechanical arms hinged at their upper points, and are attached to 8-in by 4-in vertical 'I' sections positioned around the 15-ft diameter furnace. The loading and unloading system is synchronized with the furnace doors, and the mechanical movement of the doors provides the signal for the operation of the pneumatic equipment.

Although the furnace temperature is high, it is understood that this does not interfere with the operation of the pneumatic equipment or the air rams as the furnace is encased in an 18-in thick firebrick outer wall.

In operation, the cold forging billets are transferred from the loading point on to an automatic billet-lift by a gravity conveyor. When a billet has been transferred on to the loading device, the latter rises automatically, so inserting the billet into its gripper jaws. When the loading device has reached the top of the lift, a limit switch operates to close the jaws gripping the billet and to initiate the return of the loading device to its normal 'down' position, leaving the billet ready for loading into the furnace. Working in conjunction with the billet-lift is an arrangement which meters the billets one at a time on to the lift, and ensures that a billet cannot be transferred on to the lift when the latter is raised.

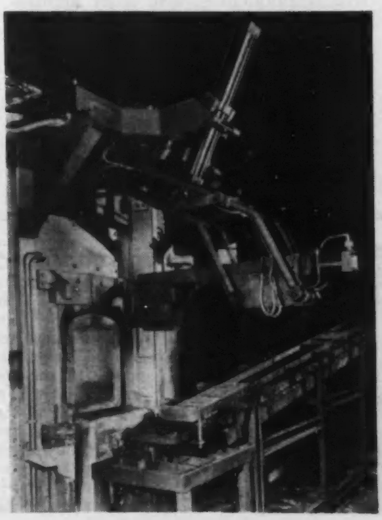
On receiving a signal from the timer controlling the rate of operation of the furnace, the furnace-door control opens the doors of both the loading and unloading apertures of the furnace. As soon as the doors are open, the loading and unloading devices advance into the furnace, the loader depositing the billet on to the furnace hearth, and the unloader gripping the heated billet. Both devices then withdraw, the furnace doors close, and the hearth of the furnace is indexed one stroke. When both are fully withdrawn, the jaws of the unloader open, allowing the hot billet to fall on to a discharge chute for transfer to the hammer or press.

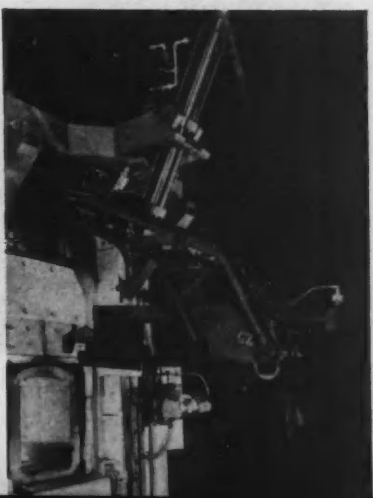


Above. Loading and unloading equipment fitted to a rotary furnace at Smiths Stampings, Coventry

Below, left. The furnace door having been opened, the loader places a billet on the furnace table

Below. A heated billet is removed and dropped on to the discharge chute





NEWS ROUND-UP

from the world of control

BUSINESS

C.J.B. form auto-control firm

Constructors John Brown have formed their automatic control division into a wholly owned subsidiary company, Automatic Control Engineering Ltd. The new company will provide the services previously provided by the division, including consultancy design, works assembly and site installation in the fields of instrumentation, automatic control, remote control and telecommunications, and laboratory engineering. The Directors of the new firm are I. J. Crosthwaite (Chairman), H. D. Walker, R. Riley (General Manager), H. H. Rosenbrock, and M. P. Atkinson (Chief Engineer). The address is: Automatic Control Engineering Ltd, Roxby Place, Seagrave Road, Fulham, London, S.W.6; telephone: Fulham 7761.

French pressure-control company

Garrett Corp. (U.S.A.), Maison Breguet (France) and Normalair — a subsidiary of Westland Aircraft—have equal shares in a new French company, Breguet-Garrett S.A. Garrett and Normalair produce air conditioning, pressurization and breathing equipment for aircraft; Maison Breguet is an important manufacturer of electrical machinery and mechanical equipment. Breguet-Garrett S.A. will manufacture pressure-control equipment for aircraft, and air conditioning and refrigeration systems for aircraft, helicopters, missiles, automobiles and electronic assemblies, under licence in France.

Gulton Industries formed

During a recent visit to London, Dr L. K. Gulton, President and Chairman of the American company Gulton Industries Inc., announced the formation of a British subsidiary. A large proportion of this firm's products in the U.S. have been supplied to the missile and space people, but Dr Gulton was anxious to emphasize that these products — mainly specialized components—have other applications in the industrial and medical fields.

The company places unusual emphasis on research, particularly research of a fundamental nature into materials. The internal division in the company between research and production is said to be far less distinct than is conventional—Dr Gulton likes to describe his organization as 'an engineering university with a profit motive'.

The exact nature and location of the subsidiary, to be known as Gulton Industries (Britain) Ltd, was not disclosed. *Control* understands, however, that it is likely that an existing British firm working in similar fields will be taken over.

Ultra's share in Miles

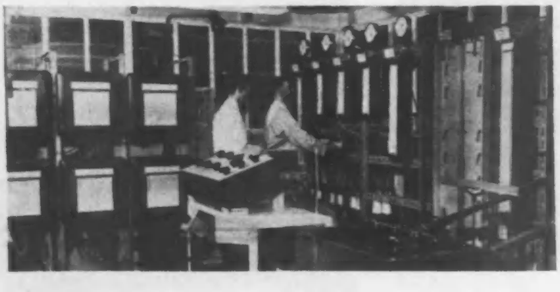
A one-third share in Miles Electronics is being purchased by Ultra Electronics, making the latter equal owners with the Miles family and Lombard Development Corp. Any association between Miles and Ultra has been mainly technical up to now: they jointly designed and manufactured the radar simulator for the de Havilland Sea Vixen, and at the moment they are working together on a radar simulator for the Blackburn Buccaneer. Miles Electronics have also produced and sold advanced nuclear reactor simulators. A. V. Edwards and L. R. Crawford, Directors of Ultra Electronics, are joining Miles Electronics' Board.

Desoutter's automation firm

Carter Stevens (Automation) Ltd has been formed by Desoutter Brothers (Holdings) Ltd, to carry on the businesses of Carter Stevens & Co. (Engineering), Carter Stevens & Co (Automation), and Blakeman Designs, all of Coventry. Desoutter will subscribe 76% of the issued share capital which, in the first instance, will be in the region of £50,000. The Board of the new company has been joined by W. J. Carter, P. Stevens, G. D. Simpson, R. E. Stockley and D. W. Blakeman.

Vickers Inc. in Britain

Negotiations are being concluded between Vickers Inc. of Detroit and Stein & Atkinson Ltd, whereby Vickers will acquire the latter company's interest in Stein Atkinson Vickers Hydraulics Ltd, thereby acquiring the entire capital. Stein Atkinson Vickers,



TAKING HECTOR'S TEMPERATURE Fairey Engineering is the major contractor for the U.K.A.E.A.'s Hector—heated experimental carbon thermal oscillator reactor, a zero-energy experimental device for Winfrith Heath. Hector will have a central test region in which various sample materials will be oscillated; the effect of the oscillating sample on the power of the reactor can be measured and related to the neutron physics properties of the sample. In Hector the test region will be maintained at up to 450°C, with temperature drift rates no greater than 0·003 deg C/min. This degree of temperature control is being investigated with the aid of a test rig and the control and instrumentation room (illustrated) at the Heston factory of Fairey Engineering, where experimental work to prove the system is in hand

ONE-PIECE. A rather unusual feature of this George Kent instrument and automatic control panel is that it is constructed as a single section. Some 16 ft long by 8 ft high and 7 ft deep, it was supplied to the order of Babcock and Wilcox for the South African Electricity Supply Commission's Hex River Power Station, for which a great deal of other Kent equipment is being supplied

who manufacture Vickers-Detroit hydraulic equipment, have just built a new factory on a twelve-acre site near Havant, Hampshire.

B.C.A.C.

Inaugural luncheon

At a luncheon held to mark the recent reconstitution of The British Conference on Automation and Computation (see these columns, November 1960) given by the B.C.A.C.'s Chairman, Sir Walter Puckey, the Secretaries or other chief executives of the 32 organizations represented in the Conference were present. Three panels have been set up: Education and Training, with Professor G. D. S. MacLellan (University of Glasgow) as Chairman; Research and Development, with J. F. Coales (University of Cambridge) as Chairman; and Public Relations, under the Chairmanship of W. C. F. Hessenberg (B.I.S.R.A.).

It was reported that arrangements were well advanced for the holding of a Conference at Harrogate from 27 to 30 June, 1961, with the general title 'Automation—Men and Money'. Plans were also in hand for the delivery, in the autumn of 1961, of the first B.C.A.C. Annual Lecture, which would be in the form of an authoritative review, by an expert in the field, of the present position and probable future development of automation procedures in British industry and commerce.

RAILWAYS

Wheel spin control

Each of three trains now going into service on London Transport's Central Line, is made up of four new motor cars with all axles motored, and four older trailer cars modernized to run with the new stock as an eight-car train. The new motor cars, which are by Cravens Ltd, have four traction motors, the two in each bogie being permanently in series. Serious consequences could ensue if the wheels driven by one motor of a pair began to spin, and, therefore, wheel-spin protective devices have been fitted. Protection is based upon the use of two differential voltage relays—one for each pair of motors. Both relays have two coils, each coil being connected across one of the pair of motors in a bogie. Should wheel spin occur on one motor, the voltage balance across the pair of motors will be disturbed, the relay will operate and open the line breakers. The traction control equipment will then return to the 'off' position, after which it will 'notch' up again automatically.

Solid-state signalling

Mullard recently demonstrated a model of a solid-state system for signal interlocking, which is being made under a contract from the British Transport Commission. It is planned to install the new system experimentally in a signal box at Henley-on-Thames during the early summer of 1961.

Traditionally, interlocking has been achieved by mechanical locks, or, in more recent installations, by conventional relays. The Mullard system comprises logic circuits in which combinations of 'and' and 'or' gates make the push-button selection of routes possible, and automatically prevent the selection of any unsafe combination of conditions. The logic circuits are built as entirely solid-state plug-in units, and the positions of all points and signals are indicated. All the circuits are arranged to 'fail safe'.

It is claimed that the system, by eliminating moving parts, will greatly reduce the long-term maintenance costs. The B.T.C. states that the adoption of electronic interlocking in projected signalling schemes will depend largely on the reliability of electronic systems in comparison with that of magnetic relays; these have been found to have a minimum life of five years when operated in sealed containers, and a failure rate of better than one in 10^7 operations.

FOOD

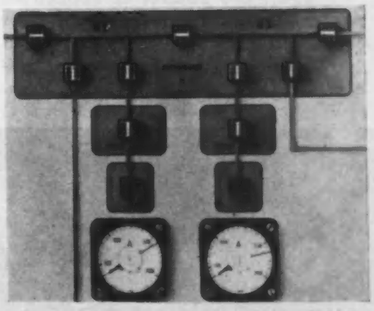
Baker Perkins' Russian contract

A contract worth £127,000 has been awarded to Baker Perkins for plant to handle and store flour in a Moscow bakery. The installation will have a total storage capacity of 420 tons and will include five automatic weighers with an arrangement recording each weighing. The flour will be pneumatically conveyed from the silos to the mixers under electronic control. Predetermined weights will be delivered in sequence, and each weight recorded for checking purposes. The plant will deliver flour to mixers, top-up service bins and record weights entirely automatically. The intention is that each delivery of flour should be as exact as possible.

SHIPPING

Indication in 'Hermes'

An interesting naval application of Dowty Electrics' three-position magnetic indicators is on the main power control panel of the recently commissioned aircraft carrier H.M.S. *Hermes*. The indicators provide three display patterns, these being formed on prisms actuated by twin solenoids. The first pattern appears when one



The main power control panel in H.M.S. 'Hermes' uses three-position magnetic indicators to show the state of power supplies throughout the ship. Illustrated are a local control panel and a single three-position indicator

solenoid is energized, the second pattern when the other coil is de-energized, and the third pattern when both solenoids are de-energized. The display surface is ¼ in square, the supply needed is 0·067 A nominal at 28–30 V, and the weight of the unit is 2·2 oz. A life expectancy of over 1,000,000, operations is claimed for these indicators, which are understood to be standard equipment on many aircraft and industrial panels. Apart from their use in *Hermes'* main power control panel, they are used throughout the ship to indicate the state of power supplies feeding individual electrical and electronic equipments.

GLASS

Auto-control at Forster's Glass

Glass level control within ±0·01 in and feeder temperature control to ±0·1% is said to be achieved by Forster's Glass Co. Ltd, St. Helens, Lancs, following the introduction of an automatic control system on their furnaces and feeders. The glass level control is applied to the molten glass in the forehearth, and is achieved with the aid of electronic circular-scale controllers by Honeywell Controls, radioactive cobalt being used to detect the glass level. The cobalt unit emits a continuous signal which is amplified by an Isotopes Development amplifier and fed to the Honeywell controller. This is a continuous-balance instrument of the potentiometer type, which automatically initiates control of a variable-speed gear-box on the batch chargers.

Temperature control is applied to the channels and spouts of all glass feeders. Temperatures are controlled by Honeywell circular-scale controllers using Radiamatic radiation pyrometers for temperature detection in the channels, and thermocouples for detecting the spout temperatures.

Bottle making at Forster's Glass Co.: here bottles are emerging from feeders whose spout and channel temperatures are held within 0·01% with the aid of the Honeywell control equipment in the background

All the instruments for each furnace are panel-mounted and include Honeywell two-point strip-chart recorders for recording reference temperatures in both the working and melting ends of the furnace in conjunction with Radiamatic and thermocouple detectors. Fuel flow is controlled by George Kent instruments, and furnace pressure by Electroflo.

NEWS BRIEFS

Sperry 'flight director Gyropilot' to be fitted to six Handley Page Dart Heralds ordered by Jersey Airlines, and to three ordered by B.E.A., will enable these aircraft to make automatic i.l.s. approaches and hold height automatically.

Polaris missile-launching submarine program: Sperry Gyroscope, U.S.A., who are building a Polaris submarine simulator, have ordered over £100,000-worth of analogue computing equipment from Electronic Associates.

Electronic counters: Marconi Instruments are to manufacture the transistorized counters of Computer-Measurements Co., Sylmar, California, under a new ten-year agreement. Information on related products will be exchanged between the two companies.

Evans Electroselenium — photo-electric devices—have had a record year's trading, with a 30% increase in home sales and a 50% increase in exports.

V.t.o.l. control: Sperry Gyroscope and the Smiths Group are collaborating on the development of the automatic stabilization and flight instrumentation for the Hawker P.1127 v.t.o.l. aircraft.

Emidec 1100 data-processing system for Colgate-Palmolive, will handle sales invoicing, stock control, vehicle loading control, customers' accounts, monthly statements, daily summaries of orders and sales statistics. The machine will be delivered towards the end of 1961.

Pye are to manufacture the low-power nuclear reactors developed by American Machine & Foundry Co. for research and training applications.

Thermal power station of 2800 MW capacity being built at Konakov, outside Moscow, 'will be automated to the maximum and provided with information and calculating machines.'

Firth Cleveland are moving certain departments of their various companies from the Group's headquarters at Stornoway House, Cleveland Row, to 7 Cleveland Row, St James's, London, S.W.1.

ELECTRICITY

Power station actuation

The remote control and mechanical handling firm, Teleflex Products, have informed *Control*, that they are to supply actuating equipment for two of the C.E.G.B.'s new power stations, that at Richborough on the Kent coast, and West Thurrock power station, Essex.

At the coal-fired station at West Thurrock, Teleflex are providing 74 actuators per boiler. These will be the first purely electro-mechanical actuators installed in Britain to operate fuel impellers, air registers and gas and air dampers. The two boilers, of an eventual four, are being designed and manufactured for outdoor operation by Babcock & Wilcox, and the turbo-alternator set will give an output of 200 MW. Evershed & Vignoles are supplying the instrumentation for combustion, steam and feed-water control. Teleflex actuators will also operate the isolating valves on the eight pulverized fuel mills on each of the first two boilers. The contract should be completed early this year.

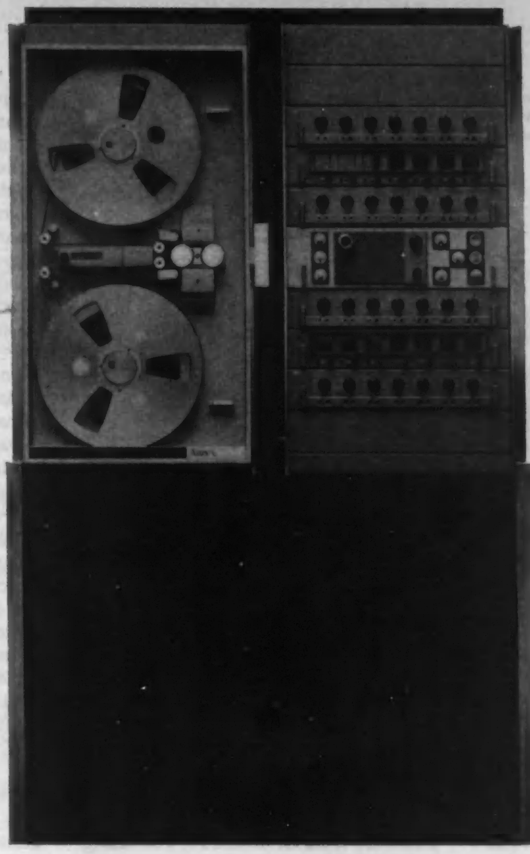
The second contract is to supply 74 actuators to the pulverized fuel station at Richborough. This station will eventually consist of three 120 MW sets and the Teleflex actuators will control dampers on the boilers, manufactured by John Thompson (Water Tube Boilers), from a unit control desk. The actuators are being supplied through Electroflo Meters who are providing the control desks and cubicles, together with the instrumentation and automatic boiler control.

TRANSPORT

Lock gate control

British Waterways' modernization program includes modifying certain manually-operated locks to hydraulic actuation, and a typical example is at Diglis Lock, Worcester. There are two locks at Diglis, a large one measuring 142 ft by 30 ft, and a small, 94 ft by 20 ft, lock. Each has two 30-ft high gates, the two outer gates of the large lock weighing about fourteen tons apiece, while each of the inner gates weighs twelve tons. The small lock-gates weigh around eight or ten tons.

So far, the smaller lock only is hydraulically operated, the large lock being still in the process of conversion from manual to hydraulic control. The installation, which is housed on an island between the two locks, consists primarily of a Dowty-Rotol power pack with control valves by Dowty



The AMPEX FR-600 is an advanced-design data recorder
with twice the capacity of conventional recorders. Most analogue recorders can only record 24 minutes of 100 Kc data on a 14-inch reel of 1 mil tape. The FR-600 will record 48 minutes of the same data on the same reel of tape. The reason—greater bandwidth at a given speed ... 125 Kc at 30 ips, for example. Many data-runs are 30 minutes or longer, requiring a stand-by recorder to pick up where the first leaves off ... an expensive price for a few extra minutes of recording time. The FR-600 literally does the work of two conventional machines by enabling double record time for any given bandwidth, or double bandwidth for any given record time ... 250 Kc at 60 ips, for example. Another cost-saving feature is the tape shuttle which automatically scans any portion of the tape, eliminating the need for a separate loop recorder. Modular plug-in, solid-state electronics warm up in less than 10 minutes, and FM amplifier drift is less than one percent in 24 hours. Other advanced features of the FR-600 include pneumatic tape guiding, tension sensing and control, adjustable search speed and fourteen miniature monitor oscilloscopes. For complete information write Ampex Great Britain Limited, Arkwright Road, Reading, Berkshire, England. AMPEX

Manual and hydraulic operation at British Waterways' Diglis Lock where Dowty-Rotol equipment is now actuating the lock's gates

Hydraulics. The power pack comprises a 7½ h.p., 400-volt electric motor driving a Dowty gear pump immersed in a 12 gal tank of hydraulic fluid. At 1500 rev/min, the pump delivers 6 gal/min at a pressure of 1500 lbf/in² to the hydraulic system through a relief valve.

The control panels are at each end of the cabin, illustrated, and directly under the window overlooking the gates being operated. Hydraulic power from the pump passes to open-centre control valves, and is directed to either end of a hydraulic jack connected to each lock gate. Safety features include shear pins where the jack rods are connected to the gates, a cross-head sliding arrangement which supports and guides the jack rods, and a restrictor-relief valve mechanism. The latter provides metering characteristics if the gates tend to stick, or are butted by a craft within the lock.

Lock operation under hydraulic actuation is said to be both swift and trouble-free. A craft enters the lock through two open gates which are then closed by switching on the power pack and moving two control valves. Water flows into or out of the lock via a 6 ft by 4 ft sluice gate actuated by an electric motor working a worm thread. Meanwhile the lock-keeper walks across his control cabin and moves another two levers to open the outlet gates through which the boat leaves the lock.

METEOROLOGY

Automatic weather-plotting

The U.S. Weather Bureau is now using an electronic computer-plotter that mechanically draws a complete weather map of the northern hemisphere in less than three minutes.

Known as the 'weather plotter', the electronic unit reads weather information supplied in numerical form on magnetic tape and presents the information to a digital-to-analogue converter. The converter instructs the plotter to automatically draw isobars on a 30 in by 30 in map.

According to Dr G. P. Cressman, Director of the U.S. Weather Bureau's National Meteorological Centre, the plotter, which was developed by Electronic Associates, produces a complete weather map in less than three minutes, compared with approximately twenty minutes required by the former hand-drawn method. He also remarked that this automatic, electronically controlled method produces maps that are far more accurate than those hand-drawn. Information is fed into the plotter from more than 500 weather observation stations throughout the northern hemisphere, observations being taken at noon and midnight and fed into the Centre by teleprinter.

Forecasts, ranging from twelve to 72 hours ahead, are programmed on a computer and recorded on magnetic tape. The tape is then put on the plotter for reading, conversion and map plotting.

Immediately after each map is produced, it is distributed by facsimile to 26 stations throughout the United States for use in local and regional weather forecasting. Maps are also distributed by the same method to over 600 military airfields and stations, airlines, universities and commercial weather forecasters.

According to Electronic Associates, the weather plotter is a development of their range of data-plotting equipment, which is being introduced for industrial applications such as the automatic production of engineering drawings, highway planning, map construction and data reduction.

PETROLEUM

Auto-scanner for Kuwait

Automatic alarm scanning on 100 pre-set temperature points at the Kuwait Oil refinery, Kuwait, will be by means of a one-point-per-second unit newly completed by Honeywell Controls for the main contractors, Harton and Co. Temperature points are indicated by neon lamps in five groups of twenty, each lamp having an associated toggle switch, for manual verification using a common vertical precision indicator, mounted below. The main control panel contains start and stop push-buttons, auto-manual changeover, manual step push-button, lamp test and calibration switch. Nixie lights identify the point being scanned.

The neon tubes themselves provide the alarm memory. Each lamp assembly comprises a trigger tube and an indicator. If an alarm occurs, the individual indicator will remain illuminated and a klaxon will sound; during subsequent scanning, however, the indication only will remain, and the audible alarm will not be repeated.

NEWSBRIEFS

American Association of Cost Engineers have formed a British Group—Chairman, J. H. Herbert of Kellogg International, Deputy Chairman, K. M. Curwen of Albright & Wilson, Secretary, T. B. Woods of Humphreys & Glasgow, and Treasurer, G. F. Kirby of C.J.B. Details: T. B. Woods, 32 Spring Close, Sherborne St. John, Basingstoke, Hants.

Equipment rental: Southern Instruments are now able to rent comprehensive electronic equipment to users through their associates, Instrument Rentals Ltd.

Brass plugs and sockets in Smart & Brown's M4 range, have received joint service R.C.S.C. approval number 1348/1 dated December 1, 1960.

Switchgear orders: J. G. Statter & Co., a Metal Industries company, have received orders for £40,000-worth of switchgear from Johannesburg municipality, £38,000-worth from the Admiralty for Devonport and Portsmouth dockyards, and £21,000-worth from the Central Electricity Board of Malaya. All are repeat orders.

Leo II/C computer has been installed at the Canley, Coventry, headquarters of Standard-Triumph International, the motor car manufacturers, where it will will deal initially with supply, costing and production stock control.

Pace analogue computer of 48 amplifiers has been ordered from Electronic Associates, Burgess Hill, by the Department of Chemical Engineering, University College, Swansea, who intend using it on distillation column and other chemical process problems.

Stalingrad 2415-MW hydro-electric station on the Volga, which began operating at full capacity on December 9, 'is operated by only fourteen persons per shift, thanks to the extensive use of telemechanics'.

New for Control

A monthly review of system components and instruments

For further information, circle the appropriate number on the reply card facing page 154

PUNCHED-TAPE READER

fast performance

A punched-tape reader by English Electric will read at speeds up to 1000 characters per second, and may be started and stopped up to a maximum of 30 times per second. It is readily adjustable to accept standard-width tapes with 5, 7, or 8 code-holes, and magazines are available which allow repetitive reading of a loop of tape up to 100 ft long, or 300 ft of free tape. The sensing elements are photo-transistors, compensated for temperature variation, and switches enable the operator to select odd or even parity-checks or no check, and to cause any 'all ones' character to be ignored.

Circle **No 481** on reply card

PULSE GENERATOR

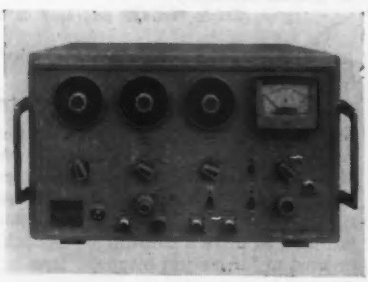
single- or double-pulse output

The Solartron GO 1005 pulse generator is suitable for the determination of transmission characteristics and transient response of amplifiers and networks, or for testing the frequency and amplitude limits of electronic counters. It provides positive- or negative-going, single or double rectangular pulses of up to 100-V amplitude at repetition rates from 10 c/s to 1 Mc/s.

Signal delay time, relative to a 10-V prepulse output, is variable over the same range as the rectangular pulse duration, 250mμs to 100ms. In double-pulse operation the leading edge of the first rectangular pulse coincides with the prepulse, and the leading edge of the second identical rectangular pulse occurs after the set signal-delay. A delayed-prepulse is also available approximately 250 mμsecs. after the prepulse, so providing a trigger output which may be made to coincide exactly with the leading edge of the main rectangular pulse.

Circle **No 482** on reply card

Variable delay



DIGITAL CLOCK

output for printer

A unit by Microcell derives its basic 50-c/s drive-frequency from the mains; transistor stages divide this down to 1 c/s, and subsequent division by miniature plug-in uniselectors gives hours, minutes, and seconds. These are displayed on 6 digital indicators.

Three output-levels

Programmed time-intervals are 1, 2, 5, 10, 20, 30, or 60 minutes, and a 24-hole pin-board selects precise hourly times. Programmed output-level is −24 V, −12 V, +12 V (either 'on' or 'off'), or contacts, either make or break; all contacts open or close for 500 ms. The output for the printer is 45 lines, 6 of which are energized at any one time.

Circle **No 483** on reply card

STABILIZED VOLTAGE SOURCE

low ripple

A self-contained unit with an output of approximately 1 V d.c. is made in three models for inputs of 107–127 V a.c., 210–255 V a.c., and 24–31 V d.c. respectively. Stability is such that the output changes by 0·001% for a 10% change in input, and the temperature coefficient is ±0·001%/degC. Output current is 10 mA ±0·25 mA, and output load 105 Ω ±4 Ω.

Made by Communications (Air) Ltd, the Convolt may be operated for long periods on either open- or short-circuit without damage. Ripple is less than 0·1 mV, and warm-up time is 5 min.

Circle **No 484** on reply card

VOLT- AND OHM-METER

polarity indicating

Readings of alternating and direct voltages from 1 mV to 1·1 kV, and resistance up to 1·1 MΩ, are displayed on a four-digit indicator, and may be recorded by direct coupling to a printer and/or a reperforator control-unit. Accuracy of the direct-voltage ranges is 0·1% full scale ± ½ least-significant count, and of the alternating-voltage and resistance ranges is 0·25% full scale ± 1 count. Made by Venner Electronics, the D.V.O.M. is constructed from transistor plug-in units and uses no stepping switches or relays.

Circle **No 485** on reply card

PULSE POLAROGRAPH

high sensitivity

A pulse polarograph, developed at Harwell, overcomes the limitations of square-wave polarography when applied

Sensitive, accurate

to irreversible reductions, and has the advantage of being capable of operation with very dilute base electrolytes.

It produces both normal and derivative polarograms, and detects reversibly and irreversibly reduced ions at concentrations of $1/10^8$ and $1/10^7$ respectively. Effects due to residual current, and to high concentrations of ions reducing at a lower potential, have been largely eliminated. Made by Southern Instruments, the A 1655 uses a 12-in chart recorder.

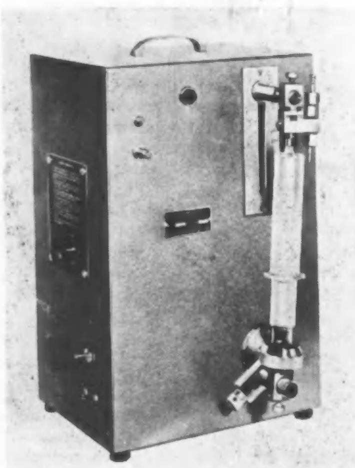
Circle **No 486** on reply card

FILLING MACHINE

fully automatic

Available in the U.K. from Shandon Scientific is an automatic filling-machine which dispenses pre-measured quantities of liquid continuously at a uniform selected speed.

The Filamatic may be fitted with glass or stainless-steel cylinders witn capacities from 1 to 50 ml, and special models are



Capacities up to 1040 ml

available up to 1040 ml capacity. The machine handles any free-flowing liquid, and has an accuracy better than 1%. It incorporates an electronically-controlled variable-speed drive, providing stepless speed-control at constant torque regardless of variations in load.

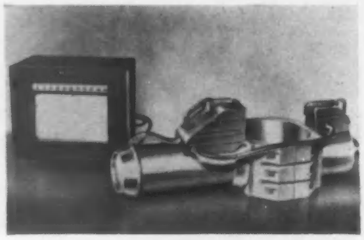
Circle **No 487** on reply card

DENSITY GAUGE

automatic standardization

A density gauge by Saunders-Roe and Nuclear Enterprises will indicate density changes in liquids, solids, slurries, etc., without contact with the material under inspection. It uses a caesium 137 source and a 5-in diameter 2-in thick phosphor mounted on a 5-in photo-multiplier. An automatic standardization system switches itself in for one minute in every ten, and compensates for decay in the measuring source.

Calibration of the standard model is accurate to 0·05% and under normal



Low drift

conditions the drift is less than 0·05% in 10 min. Response time can be varied from 1-100s. The system produces a continuous record, using a Honeywell potentiometric recorder.

Circle **No 488** on reply card

LEVEL CONTROLLER

vibrating probe

A system by Firth Cleveland is designed to indicate when the liquid or granular content of a hopper reaches a pre-determined level. The detector is a vibrating probe, which is stilled when the material being measured comes into contact with it. This actuates a control relay in the separately-housed amplifier unit, which illuminates one of two coloured warning lamps appropriate to the state of the tank contents. (The lamps are mounted on the cover of the unit and are visible from a wide angle.)

The probe will work in tanks at pressures up to 250 lbf/in², over a temperature range from − 40 to + 200°C. Ambient range for the amplifier is − 10 to + 40°C, and the unit will function from 200- to 250-V, 50-c/s mains supplies.

Circle **No 489** on reply card

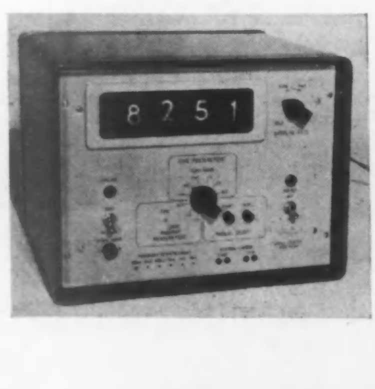
DIGITAL COUNTER

high input-impedance

This unit achieves a wide viewing-angle by using projection in-line indicators. Four digits give counts up to 9,999, and a separate indicator shows when the maximum count has been exceeded.

Frequencies between 0·1 c/s and 120 kc/s may be measured, using counting periods of 0·1, 1·0, or 10s, but the counting period may also be manually controlled. Time-intervals defined by electrical signals or contact closures may be

Clear indication



measured in clock-units of 0·1 ms to 10s, in decade steps, up to the maximum count. The clock-units, which are derived from a crystal-controlled source, are also available at outlet sockets on the front panel as negative-going 10-V pulses; the 0·1-ms pulse as a 1:1 square wave, the others as 1:4 square waves. The M1154 is made by Southern Instruments.

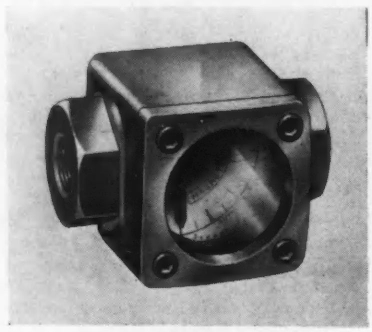
Circle **No 490** on reply card

FLOW INDICATOR

magnetic system

A range of indicators by Sir W. H. Bailey may be used for liquids of almost any viscosity, such as thick oils, and will indicate flow either horizontally or vertically-upwards.

As the fluid travels through the chamber of the indicator it moves a hinged



Handles opaque fluids

metal flap incorporating a magnet which operates a pointer against a scale; these are in a separate chamber so that the fluid cannot obscure the window. The Magnetel is available in standard ½-, ¾-, 1-, and 1½-in sizes, with ends screwed B.S.P.T.

Circle **No 491** on reply card

LEVEL INDICATOR

continuous operation

The Levelrator, made by Thomas Industrial Automation, gives continuous indication of the contents of tanks, hoppers, etc, and will also operate alarms.

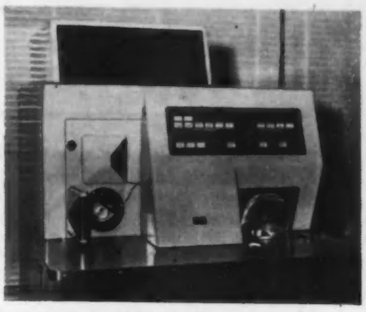
The control unit, consisting of a stabilized power supply, alarm relay circuits and built-in calibrating instruments, is housed in a weatherproof case. This may be situated up to 150 ft from the electrode unit. The built-in calibrating instrument has a scale length of 2½ in graded in 2% divisions and can be used as a local indicator.

Circle **No 492** on reply card

ELECTRONIC READER

rapid, accurate

Solartron's electronic reading automaton reads up to 300 printed characters per second, and produces coded signals corresponding to the read characters. These signals may be fed directly to a computer, used to drive a card- or tape-punch, or used to 'write' on magnetic tape.



Reads 300 characters per second

The unit reads the digits 0–9, and 10d, 11d, and ½d, plus and minus signs, and a few letters of the alphabet. The output of the reader is an electric pulse on a significant wire; there is one wire for each character of the machine's range, and a reject wire for recorded characters which cannot be read.

Circle **No 493** on reply card

SOIL DENSITY METER

radio-active series

Developed by Soil Mechanics Ltd, in association with Dynatron, a meter determines both density and moisture content of soil to an accuracy of 1·5%. The density system uses a caesium source held in the end of a stainless steel probe, and a Geiger-Müller tube. The moisture system uses a radium beryllium source, and a proportional counter. A locking device fitted to the probe prevents accidental exposure.

The scaling unit has five counting display tubes enabling a total of 10^5 counts to be registered. It includes a stabilized supply for the Geiger tube, a test-pulse generator, and a built-in timer. Power is provided by a compact re-chargeable battery which gives 10 hours continuous operation.

Circle **No 494** on reply card

POTENTIOMETRIC RECORDER

force-balance system

A range of recorders by Kelvin Hughes uses a force-balance system instead of the more conventional slide-wire; a detailed description is given in this month's *Ideas Applied*, page 106.

Accuracy is quoted as ±0·25% f.s.d. for ranges of 10 mV and above, and ±0·5% for lower ranges, provided that the source impedance does not exceed 200 Ω. Effective chart-width is 10½ in, the roll holding up to 1000 in of chart. Six chart-speeds of 4, 8, or 16 cm/h, or 2, 4, or 8 in/h, are obtainable with all standard instruments. Other speeds up to 500 cm/h or 200 in/h may be obtained to order.

Six standard chart-speeds

Circle **No 495** on reply card

QUICK LOOKS

Signal generator. A Servomex instrument provides random signal inputs for testing automatic control systems and simulating background noise in system analogues. It produces noise with a Gaussian probability distribution of amplitude, and gives constant power per unit bandwidth in the range 0·04 to 10 c/s. Fixed and variable outputs are available delivering up to 5 V r.m.s. from a low impedance source.

Circle **No 496** on reply card

Timing unit. Binary Electronics' (U.S.A.) model 101 timer generates crystal-referenced pulses. Pulse rates are 0·1, 1·0, 10 and 100 pulses/s. Each rate is pulse-width modulated to allow easy detection of the different rates. Solid state circuitry is used throughout.

Circle **No 497** on reply card

Miniature potentiometers. Very small potentiometers by Miniature Electronic Components are available in double and triple form, either type being housed in a one-piece aluminium case. Resistance range is from 10 Ω to 125 kΩ in 17 standard values, and the operating temperature range is − 55 to + 150°C. Dissipation at 50°C may be up to 2·75 W.

Circle **No 498** on reply card

Air valve. A three-position four-way valve by Mechanical Air Controls (U.S.A.) is solenoid operated and may be 'inched' to any position and held. It will operate at pressures from vacuum to 150 lbf/in², and may have either an open or closed centre.

Circle **No 499** on reply card

Oil-burner control. An automatic unit (57F) by Danfoss uses a photo-resistor as sensing element. It needs no warm-up time, and guards against short-circuiting or earthing of the photo-unit leads.

Circle **No 500** on reply card

Thickness tester. An ultrasonic thickness tester by Knetz is available in the U.K. from Aveley Electric. The effective depth-range is 1–70 cm for flaw detection; for thickness-gauging the maximum range is about 20 mm, dependent on frequency and attenuation of the material under test. Circle **No 501** on reply card

Industrial relay. A control relay by Square D, designated 70001 type D, has 10-A contacts which will switch a.c. or d.c. Three types provide 4, 6, or 10 contacts, and coils are available for voltages up to 250 V d.c.

Circle **No 502** on reply card

Potentiometer. A range of plastic precision potentiometers by Ace Electronic (U.S.A.) is available in the U.K. from Scientific Furnishings. Life expectancy is better than 2×10^7 cycles, and standard linearity is 0·5%. Resistance range is 100 Ω to 250 kΩ (1 1/16 in dia.), and 100 Ω to 150 kΩ (½ in dia). Operational noise is claimed to be very low.

Circle **No 503** on reply card

Output transistor. Intended as an alternative to the recently introduced OC84, OC83 is a medium-power output transistor of the germanium *p-n-p* alloy type, for industrial a.f. amplifier and switching applications. It has a peak current of 1 A and the current gain is linear; at 50 mA the minimum gain is 50. Made by Mullard.

Circle **No 504** on reply card

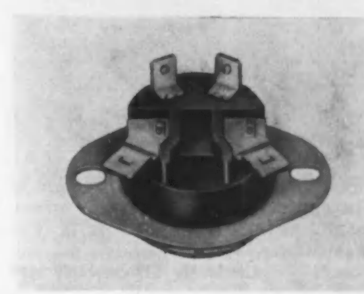
E.H.T. units by Grundy and Partners have a power-output of 750 VA at voltages between 5 and 20 kV d.c., with either positive or negative earth. Input voltage may be from 110–250 V a.c., 50–60 c/s; power consumption is about 1 kW.

Circle **No 505** on reply card

Diode. A micro-miniature diode has been developed by Hughes Semiconductor Division (U.S.A.). It is 0·03 in long by 0·05 in diameter. Maximum forward current is 100 mA at 1 V; reverse current is 0·1 μA at 50 V d.c. Operating temperature range is −55 to +100°C.

Circle **No 506** on reply card

Disk thermostat. Texas Instruments (U.S.A.) type 20450 has an integral line-voltage heater which may be varied to change the response of the thermal element to ambient temperature. It is available with a single-pole, single-throw, or with a single-pole, double-throw contact arrangement.



Circle **No 507** on reply card

Power supply. A stabilized power supply by W. G. Pye has d.c. outputs from 0-500 V, a fixed negative output of −250V, and a variable negative output of 0 to −250V, all with less than 3mV ripple. Two non-stabilized a.c. supplies each provide 6·3 V at 5 A.

Circle **No 508** on reply card

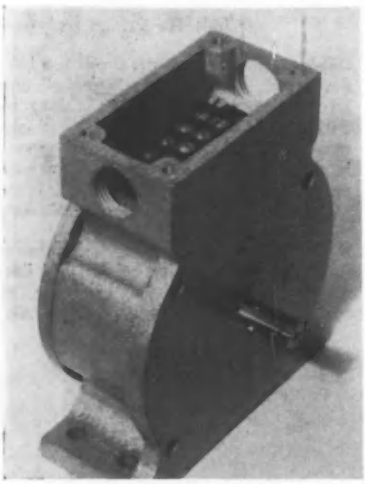
Low-pressure transducer. Available with any range between 0-10 and 0-100 lbf/in², this transducer is intended for low-pressure systems which may be subjected to high shock-pressures. A stop restricts the movement of the diaphragm so that it will withstand pressures up to 1000

lbf/in.². The G304 transducer is made by Southern Instruments.
Circle **No 509** on reply card

Transistor tester. A unit by Grundy and Partners is designed for use in conjunction with multi-range meters with a 1-mA basic movement or better. Measurements include collector-emitter and collector-base leakage-currents at a p.d. of 4·5 V.
Circle **No 510** on reply card

Resistors. Alma Components have extended their range of resistors so that an absolute accuracy of ±0·01% is guaranteed over the range 100 Ω to 100 kΩ for both 1-W (type S1) and 2-W (type L) ratings.
Circle **No 511** on reply card

Switching unit. A high-speed unit by Lancashire Dynamo Electronic Products is designed to operate from the rotation of a shaft. Two sets of heavy-duty leaf-spring contacts are included, and the

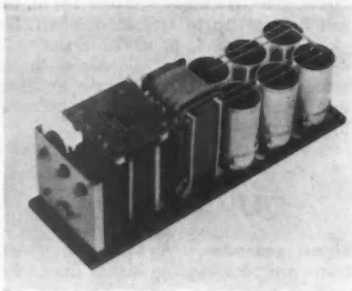


operation is determined by the form of the operating cams. The case is splash-proof, and the input-shaft is of ⅜ in. diameter.
Circle **No 512** on reply card

Tachometer. F. & G. Electric's unit is for measuring the speed of internal combustion engines. It operates from the low tension side of the ignition, and is claimed to be accurate to 1·5% f.s.d. Range is 0–5000 rev/min.
Circle **No 513** on reply card

Digital modules. Manufactured by Packard Bell (U.S.A.), 200-kc/s digital modules are based on 4 × 4 in glass-based printed-circuit cards incorporating a 35-pin connector. Four identical independent flip-flop circuits are provided, each including set and reset diodes, and gates for use as a binary counter or shift register.
Circle **No 514** on reply card

Power supplies. A range of stabilized d.c. power-supplies is available from Claude Lyons. A transistor feed-back amplifier continuously monitors the output-voltage, and adjusts the current in



the control winding of a transductor to maintain constant output voltage. Ripple is in the order of 1%. Five models cover a range of outputs from 12 V at 8 A to 48 V at 2 A.
Circle **No 515** on reply card

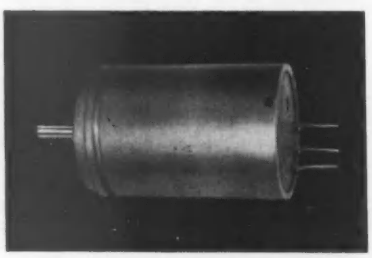
Proportioning pump. A two-speed unit by Technicon allows their Auto Analyser to run ten or twelve different analyses daily on the same machine with minimum changeover. Two timers automatically control aspiration period and cycle time. Circle **No 516** on reply card

Portable oscillator. An instrument by Solartron provides symmetrical low-distortion sinewave outputs, of 0° and 180° phase relationship, over the frequency range of 10 c/s to 1 Mc/s. A balance control is incorporated to obtain symmetry about earth at low frequencies. A balanced Wien - network with variable-capacity tuning gives a frequency accuracy within ±2·5%. The frequency stability over an eight hour period is ±0·2% of set frequency.
Circle **No 517** on reply card

Transistor. A silicon diffused *n-p-n* transistor for ferrite-core switching circuits and power oscillators will work at frequencies up to about 10 Mc/s. Made by S.T.C., the TK200A has a maximum dissipation of 2·5 W at 25°C.
Circle **No 518** on reply card

Manometer. A solid-block 60-in manometer by Combustion Instruments is calibrated 0-30 lbf/in.². A feature of this instrument is that it may be carried about without plugging the connexions.
Circle **No 519** on reply card

Rotary transducer. Available from Sylvan Ginsbury (U.S.A.) the RK 3600 variable-permeance transducer has a



maximum shaft rotation of 3600°. Excitation frequency is 400 c/s, maximum input voltage 26V r.m.s., and linearity and resolution 1% and 0·01% respectively. Circle **No 520** on reply card

INDUSTRIAL PUBLICATIONS

Rolling-mill engineering by Davy-United is described in a lavishly illustrated publication from the Davy-Ashmore Group.
Circle **No 544** on reply card

Photography as an aid to commerce and industry is the subject of an illustrated booklet from Kodak.
Circle **No 545** on reply card

Vacuum equipment including pumps, high-vacuum valves, etc, is described in a booklet from Leybold (Germany).
Circle **No 546** on reply card

Computing. Details of the Solartron analogue computer installation are given in a recent leaflet.
Circle **No 547** on reply card

Compressed-air filter. Doulton's F.101 is described in their leaflet F2A.
Circle **No 548** on reply card

Instruments by Dawe are listed in an abridged catalogue in French.
Circle **No 549** on reply card

Power supply. Pye's stabilized unit (catalogue 8440) is described in a recent leaflet.
Circle **No 550** on reply card

Valves by General Kinetics Corporation (U.S.A.) are listed in catalogue GV.102 from James Gordon.
Circle **No 551** on reply card

'New ways with rubber' is the title of a booklet issued by D.S.I.R.
Circle **No 552** on reply card

Anhydric incubators and an intermediate oven by Baird and Tatlock are described in leaflets SL 22 and 21 respectively.
Circle **No 553** on reply card

Control components by Automatic Electric (U.S.A.) are listed in a recent brochure. Circle **No 554** on reply card

Glass-fibre woven tapes are the subject of publication D4 from Turner Brothers.
Circle **No 555** on reply card

'Pneutomation News' is the title of a publication now being issued by Lang Pneumatic. Circle **No 556** on reply card

Electronic equipment is illustrated in a short-form catalogue from E.M.I. Electronics. Circle **No 557** on reply card

Porous plastic. Vyon, made by Porous Plastics Ltd, is the subject of their recent booklet.
Circle **No 558** on reply card

Flameproof electronic control-units by Elcontrol are described in data sheet FP, issue 1. Circle **No 559** on reply card

Ultrasonic testing. Ultrasonoscope's Mk 2 unit is featured in a catalogue which also contains general information on metal testing by ultrasonics.
Circle **No 560** on reply card

LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.S. British Computer Society. Brit.I.R.E. British Institution of Radio Engineers. I.E.E. Institution of Electrical Engineers. I.Mech.E. Institution of Mechanical Engineers. I.S.A. Instrument Society of America. R.Ae.S. Royal Aeronautical Society. S.I.T. Society of Instrument Technology.

FRIDAY 6—SATURDAY 7 JANUARY 1961
Rocket Propulsion Symposium at Cranfield. Joint meeting with the College of Aeronautics and the British Interplanetary Society. R.Ae.S.

MONDAY 9—WEDNESDAY 11 JANUARY 1961
7th National Symposium on Reliability and Quality Control. Bellevue-Stafford Hotel, Philadelphia, Pa., U.S.A. Details: R. Brewer, G.E.C. Research Laboratories, Wembley, Middx.

WEDNESDAY 11 JANUARY 1961
Ergonomics—fitting the job to the worker by C. B. Frisby. 6 p.m. Royal Society of Arts, John Adam St, Adelphi, London, W.C.2. Details: The Secretary, Royal Society of Arts.

MONDAY 16—FRIDAY 20 JANUARY 1961
Physical Society Exhibition, R.H.S. Halls, Westminster, London, S.W.1.

TUESDAY 17—THURSDAY 19 JANUARY 1961
I.S.A. Instrument-Automation Conference and Exhibition. Sheraton-Jefferson Hotel, and Kiel Auditorium, St. Louis, Mo., U.S.A. Details: Wm. H. Kushnick, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

WEDNESDAY 18 JANUARY 1961
A general method of digital network analysis particularly suitable for use with low-speed computers by M. N. John. 5.30 p.m. I.E.E.
Digital computers in power system analysis by P. P. Gupta and Professor M. W. Humphrey Davies. 5.30 p.m. I.E.E.

MONDAY 23 JANUARY 1961
Cybernetics by Professor J. C. West. Royal Institution, Colquitt St., Liverpool. 6.30 p.m. I.E.E.

TUESDAY 24 JANUARY 1961
Discussion on *Machine-tool control*. Opened by E. H. Frost-Smith. 5.30 p.m. I.E.E.

TUESDAY 31 JANUARY 1961
Instrumentation past, present and future by L. S. Yoxall. 7 p.m. S.I.T.

WEDNESDAY 8 FEBRUARY 1961
Flight testing of v.t.o.l. aircraft by T. W. Brooke-Smith. 7.30 p.m. R.Ae.S., 4 Hamilton Place, W.1.

WEDNESDAY 15—FRIDAY 17 FEBRUARY 1961
1961 International Solid-state Circuits Conference. University of Pennsylvania and the Sheraton Hotel, Philadelphia, Pa., U.S.A.

MONDAY 16 FEBRUARY 1961
Transistors and all that by L. J. Davies. Central Hall, Westminster. I.E.E.

TUESDAY 17— SATURDAY 21 FEBRUARY 1961
24th International Components Show, Parc des Expositions, Paris, France.

4th International Exhibition of Electronic Components. Details: F.N.I.E., 25 Rue de Lubeck, Paris 16, France.

MONDAY 20—SATURDAY 25 FEBRUARY 1961
International Convention on Semi-Conductor Devices. Details: Société Francaise des Electroniciens et des Radioélectriciens, 10 Avenue Pierre-Larousse, Malakoff (Seine) France.

FRIDAY 3 MARCH 1961
Helicopter approach aids by H. W. Mitchell and S. G. Lennox. 7 p.m. R.Ae.S., 4 Hamilton Place, W.1.

TUESDAY 7 MARCH 1961
Guided weapon control equipment by John Dent. 6 p.m. R.Ae.S., 4 Hamilton Place, W.1.

WEDNESDAY 8—FRIDAY 10 MARCH 1961
11th Annual I.S.A. Conference on *Instrumentation for the Iron and Steel Industry*, Roosevelt Hotel, Pittsburgh, Pa., U.S.A. Details: Richard R. Webster, Jones & Laughlin Steel Corp. Res. Lab., 900 Agnew Avenue, Pittsburgh 30, Pa., U.S.A.

MONDAY 20— THURSDAY 23 MARCH 1961
I.R.E. National Convention, New York.

TUESDAY 21—SATURDAY 25 MARCH 1961
10th Electrical Engineers Exhibition, Earls Court. Details: Mr Joyce, Electrical Engineers Exhibition, 6 Museum House, 25 Museum St., London, W.C.1.

MONDAY 27—FRIDAY 31 MARCH 1961
3rd Symposium on *Temperature—Its measurement and control in science and industry*. Veteran's Memorial Hall and Deshler-Hilton Hotel, Columbus, Ohio, U.S.A. Sponsors: I.S.A., American Institute of Physics, National Bureau of Standards. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

LOOKING FURTHER AHEAD

MONDAY 17—WEDNESDAY 19 APRIL 1961
7th National U.S.A. Symposium on *Instrumental methods of analysis*. Shamrock-Hilton Hotel, Houston, Texas, U.S.A. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

THURSDAY 20 APRIL 1961
One-day symposium on *Air Traffic Control*. R.Ae.S., 4 Hamilton Place, W.1.

THURSDAY 20 APRIL—THURSDAY 4 MAY 1961
Engineering, Marine, Welding and Nuclear Energy Exhibition, Olympia.

SUNDAY 30 APRIL—THURSDAY 4 MAY 1961
7th National aero-space instrumentation symposium. Adolphus Hotel, Dallas, Texas. Details: W. J. Gabriel, Convair Division, General Dynamics Corp, Ft.-Worth, Texas, U.S.A.

WEDNESDAY 3—SATURDAY 13 MAY 1961
British Columbia International Trade Fair, Exhibition Park, Vancouver, Canada.

MONDAY 8—WEDNESDAY 10 MAY 1961
4th National I.S.A. Power Instrumentation Symposium. La Salle Hotel, Chicago, Ill., U.S.A. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

TUESDAY 9—WEDNESDAY 17 MAY 1961.
International Exhibition of Measurement, Control, Regulation and Automation (Mesucora) and 58th Exhibition of French Physical Society, C.N.I.T., Paris. Secrétariat Général, 40, rue de Colisée, Paris, 8, France.

WEDNESDAY 10—FRIDAY 12 MAY 1961
Pulp and Paper Instrumentation Symposium. Northland Hotel, Green Bay, Wisc., U.S.A. Sponsors: I.S.A. and T.A.P.P.I. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

FRIDAY 19 MAY—SUNDAY 4 JUNE 1961
British Trade Fair, Moscow. Details: Industrial and Trade Fairs Ltd., Russell Street, London, W.C.2.

MONDAY 22—WEDNESDAY 24 MAY 1961
10th National Telemetering Conference Hotel Morrison, Chicago, Ill., U.S.A., Sponsors: I.S.A., A.I.E.E., A.R.S., I.A.S., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

TUESDAY 30 MAY—2 JUNE 1961
Radio and Electronic Component Show, Olympia. Details: Industrial Exhibitions Ltd., 9 Argylle St., London, W.1.

TUESDAY 6—THURSDAY 8 JUNE 1961
I.S.A. Summer Instrument-Automation Conference and Exhibition, Royal York Hotel and Queen Elizabeth Hall, Toronto, Ont., Canada. Details: Wm. H. Kushnick, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

MONDAY 12 JUNE 1961
Air Pollution Instrumentation Symposium (with the June 12–16 annual meeting of the Air Pollution Control Association), Hotel Commodore, New York City, N.Y., U.S.A. Sponsors: I.S.A. and APCA. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

MONDAY 12—SATURDAY 17 JUNE 1961
Conference on *Components and materials used in electronic engineering*. Central Hall, Westminster, I.E.E.

TUESDAY 13—FRIDAY 16 JUNE 1961
3rd Biennial International Gas Chromatography Symposium, Kellogg Center, Michigan State University, East Lansing, Mich., U.S.A. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

MONDAY 26 JUNE—SATURDAY 1 JULY 1961
International Measurements Conference, (Imeko), Budapest. Details: Prof. J. F. Coales, Cambridge University, Trumpington St., Cambridge, or Imeko Secretariat, Budapest 5, P.O.B. 3, Hungary.

TUESDAY 27—FRIDAY 30 JUNE 1961
B.C.A.C. conference at Harrogate on *Automation men and money*. Details from B.C.A.C., c/o I.E.E.

WEDNESDAY 28—FRIDAY 30 JUNE 1961
2nd Joint Automatic Control Conference. University of Colorado, Boulder, Colo., U.S.A. Sponsors: I.S.A., A.I.Ch.E., A.I.E.E., A.S.M.E., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

WEDNESDAY 5—SATURDAY 9 JULY 1961
Radio techniques and space research. A convention at Oxford University. Brit.I.R.E.

WEDNESDAY 30 AUG—WEDNESDAY 6 SEPT 1961
Annual Meeting, British Association for the Advancement of Science, Norwich. Details: Secretary, B.A.A.S., 19 Adam Street, Strand, London, W.C.2.

MONDAY 4—SATURDAY 9 SEPTEMBER 1961
3rd International Session of the International Association for Analogue Computation. Belgrade, Yugoslavia. Details: Yugoslav Committee for Etan Terazije 23/VII, Belgrade, Yugoslavia.

MONDAY 4—SUNDAY 10 SEPTEMBER 1961
S.B.A.C. Flying display and exhibition, Farnborough. Details: S.B.A.C., 29 King St., St. James, London, S.W.1.

WEDNESDAY 6—FRIDAY 8 SEPTEMBER 1961
International Symposium on the *Transmission and processing of information*. Massachusetts Institute of Technology. Submission of papers is invited. Details: R. M. Fano, R.L.E., M.I.T., Cambridge 39, Mass., U.S.A.

Joint Nuclear Instrumentation Symposium. North Carolina State College, Raleigh, N.C., U.S.A. Sponsors: I.S.A., A.I.E.E., I.R.E. Details: Meetings Manager, I.S.A., 313 Sixth Avenue, Pittsburgh 22, Pa., U.S.A.

MONDAY 11 SEPTEMBER 1961
20th International Congress of Navigation. Baltimore. Details: Permanent International Association of Navigation Congresses, 60 rue Juste Lipse, Brussels.

MONDAY 11—FRIDAY 15 SEPTEMBER 1961
I.S.A. Instrument-Automation Conference and Exhibition and I.S.A.'s 16th Annual Meeting. Memorial Sports Arena, Los Angeles, California, U.S.A. Details: Wm. H. Kushnick, I.S.A., 313 Sixth Avenue, Pittsburgh, 22, Pa., U.S.A.

WEDNESDAY 4 OCT—THURSDAY 12 OCT 1961
Second Electronic Computer Exhibition and Symposium, London. Details: Mrs. S. S. Elliott, 64 Cannon Street, London, E.C.4.

WEDNESDAY 8—FRIDAY 10 NOVEMBER 1961
Conference on *Non-destructive testing in electrical engineering*. I.E.E.

Book Reviews

Computers

Numerical Methods for High Speed Computers *by* **G. N. Lance.** *Iliffe & Sons. 1960. 116 pp. £2 2s.*

It would not be correct to regard this short book of 150 pages as giving a general introduction to the principles of numerical analysis. It is rather a collection, systematically arranged, of methods that the author recommends for practical computation. Although the book is elementary, some previous acquaintance with the subject is desirable on the part of the reader, particularly in the chapter on differential equations, where the author assumes that the reader is familiar with finite differences.

The author makes a special point that he has written this book with the needs of users of digital computers in mind. In this he is of course to be commended, and it would indeed be foolish at the present time to write a book on computing with desk machines. Digital computers, however, vary very much in their capacities and in their limitations, and it is clear that when Dr Lance speaks of a digital computer he has in mind machines of limited capacity, such as that which was available to him at the Southampton University Computation Laboratory of which he was, until recently, the Director. He does not have much to say about floating-point operation, and he is much concerned with the limitations imposed by small high-speed stores. (The statement on Page 5 that the capacity of the immediate-access store of a machine is seldom greater than 256 words is surely not intended to mean what it apparently says.)

Several times the author refers to the advantages of using a very simple formula applied a large number of times, rather than a more accurate formula applied a smaller number of times. If he means to imply that simple-minded methods are always to be preferred on a digital computer, I would take issue with him. This point of view was frequently expressed in the early days of automatic computation, when machines appeared to be such wonder-workers that they could do almost anything in next to no time. However, as soon as people began to tackle problems that stretched the capabilities even of digital computers, they began to realize that there is as much scope for sophisticated and efficient methods in automatic computation as there is in desk computation. Not everyone would agree with the author's statement that finite-difference methods for solving ordinary differential equations are unsuitable for use on a digital computer because they need storage space in which to hold the differences and because special subroutines must be provided for starting and interval-changing.

The book is easy to read and the descriptions of the various methods are clearly expressed. If a second edition is called for, however, I shall be interested to see what changes the author makes, both in the selection of material and in the opinions expressed, now that he has joined an organization in which much larger digital computers will be available to him. M. V. WILKES

Computer Engineering *by* **S. A. Lebedev.** *Pergamon Press Ltd. 1960. 184 pp. £3 3s.*

This is a collection of eight very useful articles, of varying length, containing many interesting and original ideas. The first deals with the power supply of the B.E.S.M. and contains more items of interest than its title would suggest. The indications are that a considerable amount of original research has been carried out, the results of which should be of interest to those engaged in the design of computer power-packs. By far the longest paper is concerned with a detailed study of digital integrating machines. The theoretical bases upon which they are designed receives very full treatment and there are also some illustrations of their use. An article of particular interest is one of the shortest, that on automatic monitoring of a serial arithmetic unit—a novel and electronically simple idea which British computer manufacturers would do well to study. The article on basic nomenclature is in essence a short-Russian-English dictionary of digital-computer terminology. Other articles are concerned with dynamic flip-flops, ferrite cores and their reliability, and methods of selecting the required word from a dictionary.

The book is translated into excellent technical English and the practice of giving English valve equivalents is very helpful. The photolithographic process used gives a very clear reproduction of the typescript and line drawings, but the photographs reproduce much less satisfactorily. This affects in the main the article on dynamic flip-flops as it contains a large number of oscillograms, and a photograph of a pulse transformer on page 102 is particularly blurred. B. GIRLING

Synchros

Basic Synchros and Servomechanisms *by* **Van Valkenburgh, Nooger** *and* **Neville,** *Inc. Technical Press, London, 1960. 117 pp. Part 1, 114 pp. Part 2. 14s. per part*

Uniform with earlier manuals on 'basic electricity' and 'basic electronics', this two-part publication in paper covers is based on a course that was originally developed for the U.S. Navy and has since been adapted by an officer of the R.E.M.E. for British use. Boldly illustrated in an unashamedly anthropomorphic style, these books will be very helpful in apprentice-training schools and the like; they can be warmly recommended for technician training. E. N. T. MARTIN

Space

The Other Side of the Moon, *translated from the Russian by* **J. B. Sykes.** *Pergamon Press Ltd. 1960. 40 pp. 10s. 6d.*

This slim, glossy, volume is a new translation of the statement that appeared in the Russian press on October 27, 1959, and was translated in the *Soviet News,* issued free, at about the same time. The only additions are the diagrams and rather poor photographic reproductions.

The cost seems hardly justified for this somewhat superficial account of Lunik III contained in a brazenly propagandist press release. The few technical facts given and ponderously presented are combined with attempts to blind with science and to 'applaud the scientists and workers who have paved the way to the cosmos'. However, if one desires to know anything about the project, this volume appears to be the only way to acquire that knowledge. One would have thought that the declared Russian desire to 'aid the onward advance of science to the conquest of the universe' would have been better served by the publication of a more informative, purely technical, report. P. R WYKE

Literature Received

Fundamentals of Digital Instrumentation *by* **D. S. Evans.** *Hilger & Watts Ltd. 1960. 39 pp. 7s. 6d.* ★ 706

Engineering Management, Second Edition *by* **Straun A. Robertson.** *Blackie & Son Ltd. 1960. 467 pp. £1 10s.* ★ 707

Introduction to Modern Physics *by* **C. H. Blanchard, C. R. Burnett, R. G. Stoner** *and* **R. G. Weber.** *Sir Isaac Pitman & Son Ltd. 1960. 420 pp. £1 17s. 6d.* ★ 708

Automatic Language Translation *by* **Anthony G. Oettinger.** *Harvard University Press. London: Oxford University Press. 1960 380 pp. £4.* ★ 709

The Training of Graduates. *I.E.E. 1960. 34 pp. 2s.* ★ 710

★ Circle the relevant number on the reader information card facing page 154 for further information.